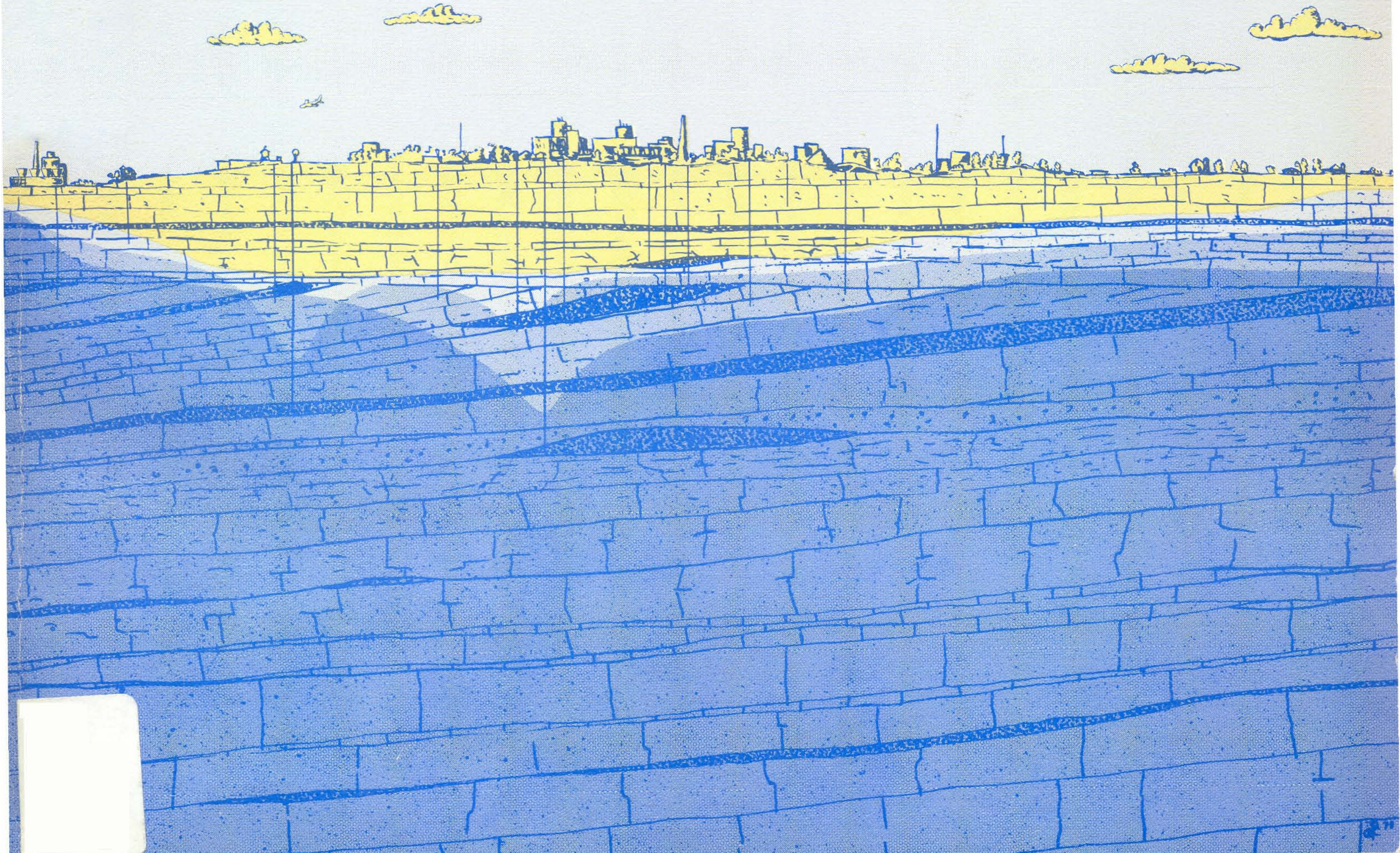
WATER RESOURCES REPORT NO. 34

WATER RESOURCES AND GEOLOGY OF THE SPRINGFIELD AREA, MO.



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1978

WATER RESOURCES AND GEOLOGY OF THE SPRINGFIELD AREA, MISSOURI

WATER RESOURCES
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AREAL GEOLOGY
By Thomas L. Thompson

ENGINEERING GEOLOGY
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ABSTRACT

Industries, municipalities, public water-supply districts, subdivisions, and rural home owners in the Springfield area are all dependent in some measure upon water from wells or springs. The major (deep) aquifer consists of over 1,000 feet of dolomite of Cambrian-Ordovician age. The upper part of this aquifer is at the surface in the extreme northeastern part of the area.

Throughout most of the area the dolomite is overlain by as much as 300 feet of cherty limestone of Mississippian age which constitutes the minor aquifer. The two aquifers are separated by the Northview Formation, which is composed of dolomitic siltstone, shale, and silty dolomite, ranging in thickness from 5 to 80 feet. Rocks making up the shallow aquifer are deeply weathered and solution features such as sinkholes and caves are common. The Northview Formation occurs near the base of the shallow aquifer, retards the downward movement of water, and acts as the confining layer to the deep aquifer.

Individual wells, open to the full section of the major aquifer, can be pumped at the rate of 2,500 gallons per minute, with about 180 feet of drawdown. From pumpage records and study of the potentiometric surface of the deep aquifer, it has been determined that the regional transmissivity is about 670 feet^2/d.

The quality of the ground water and surface water in the area is generally good. There is, of course, a potential for groundwater contamination because of the cavernous nature of the bedrock, the many sinkholes, and the presence of losing streams.

Streams incised in the upper part of the dolomite aquifer have 7-day Q_2 discharges of 0 to 0.04 ft.^{3}/s per square mile. On the other hand, streams draining the Mississippian limestone generally have 7-day Q_2 discharges of 0.05 to 0.10 feet^3/s per square mile.

Seepage runs made on Pearson, Pickerel, and Terrell Creeks during the winter and spring when there was continuous flow in the creeks defined the stream reaches where losses occur. Because the alluvium of those streams was saturated at the times of the winter and spring seepage runs, it is concluded that the stream loss is to the underlying bedrock and not just to the alluvial fill.

Flooding from heavy rains can occur in any month but is most frequent during the 3-month period from March to May. Between 1956 and 1975, two and a half times more floods occurred in May than in any other month. No flooding of any consequence occurred in August of the same period.

Approximately 8.0 M gallons of water is withdrawn per day from the deep aquifer in the Springfield area. About 5.4 M gal/d of this is for self-supplied industrial use. Analysis of a digital model of the deep aquifer indicates that additional water can be withdrawn from the deep aquifer if the groundwater users can tolerate the additional lowering of the potentiometric surface. A lowered potentiometric surface would result in increased pumping costs for all within the affected area. A lowered potentiometric surface could also result in a need for lowering pumps within wells or even the need for drilling deeper wells.

Section 1

WATER RESOURCES

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INTRODUCTION

The Springfield area has experienced considerable growth over the past several decades. The population of Springfield doubled in the past 30 years and it is now the third largest city in Missouri. This growth has been accompanied by increased demands on the water supply and by the necessity for disposing of increased amounts of wastes without contaminating the water resources. These stresses on the water resources are further complicated by the karst topography in the Springfield area.

PURPOSE AND SCOPE

The Geology and Land Survey Division of the Missouri Department of Natural Resources (formerly Missouri Geological Survey and Water Resources) started this study in cooperation with the U.S. Geological Survey. The purpose was to provide the people of the Springfield area with a documented appraisal of the total water resources of the area. Such an appraisal is necessary for long-range planning and the optimum development of the water resources.

This report describes the occurrence, distribution, and movement of ground water in the aquifers with emphasis on the dolomite aquifer. Information is provided on streamflow characteristics of the major streams in the area such as low flow, average flow, and floodflow. Data on the use and chemical quality of the ground and surface water in the area are also included.

Because of a probable increase in withdrawal of water from the major aquifer, a digital model of the major aquifer was made and a map was generated showing predicted drawdown based on an increased rate of withdrawal of 10 Mgal/d from existing wells.

Because the area is underlain by cavernous limestone, this study also includes an evaluation of the different soil, bedrock, and topographic conditions which affect the location of properly constructed lakes, lagoons, and landfills. This evaluation is included as supplementary data.

LOCATION, EXTENT, AND POPULATION

The area studied is centered around the City of Springfield and consists of most of Greene County, the northern part of Christian County, and the extreme western part of Webster County (fig. 1). The area is bounded on the south by lat. 37°00'00" N., on the north by lat. 37°22'30" N., on the east by long. 93°00'00" W., and on the west by long. 93°30'00" W. The area is approximately 750 $miles^2$. Population of the Springfield area (tbl. 1) in 1970 was estimated at 158,334 (U. S. Bureau of Census, 1970).

Table 1

POPULATION OF SPRINGFIELD AREA, MISSOURI

Town	Population
Springfield	120,096
Republic	2,411
Ozark	2,384
Nixa	1,636
Willard	1,018
Rogersville	574
Strafford	491
Clever	430
Sparta	380
Unincorporated Areas	28,914
Total Population	158,334

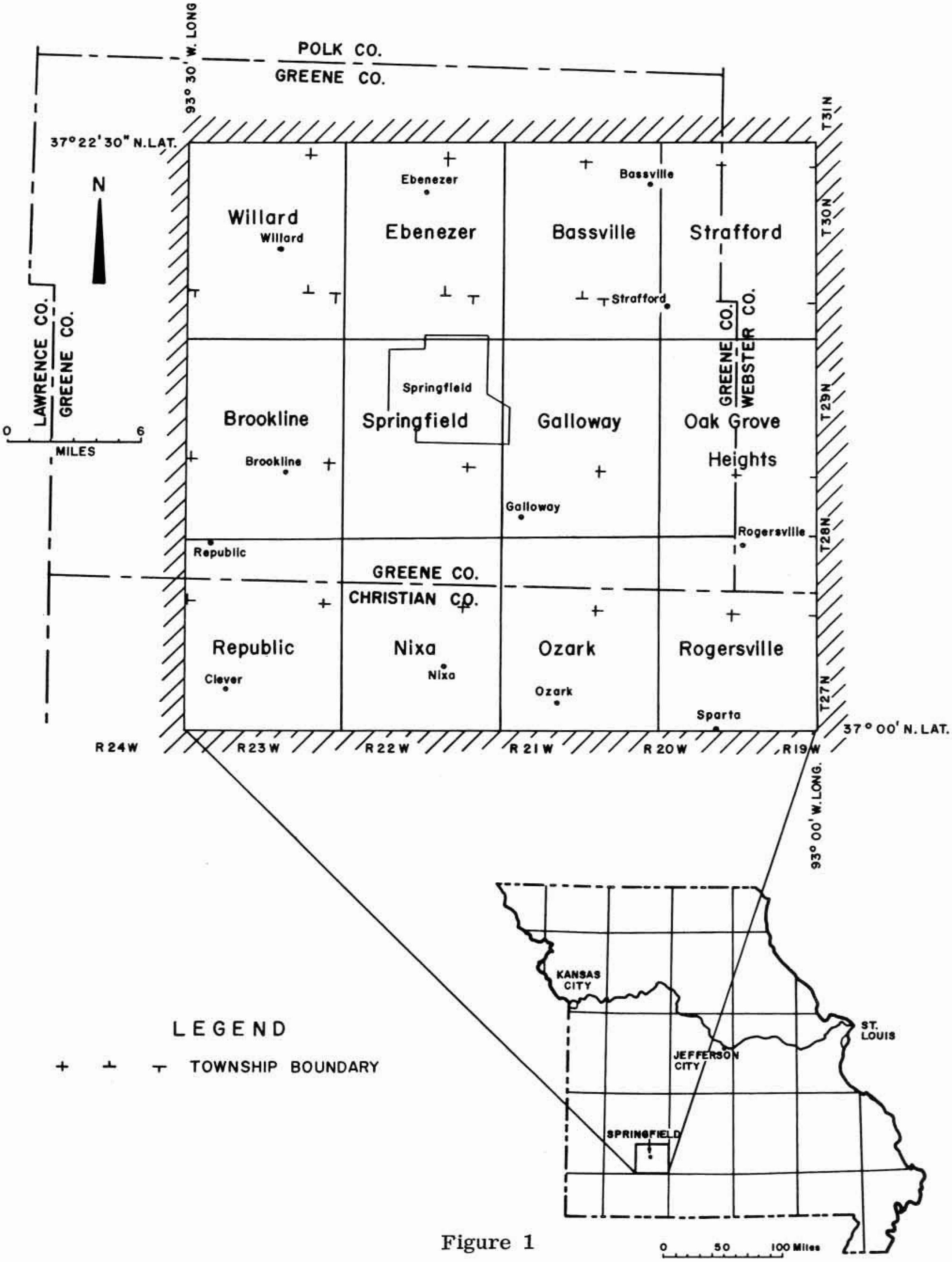


Figure 1

Map of study area showing $7\frac{1}{2}$-minute topographic map coverage.

PREVIOUS INVESTIGATIONS

The first published geologic report on Greene County appeared as Part 1, Volume XII of the Missouri Geological Survey (Shepard, 1898, p. 13-245). It is interesting to note that Jordan Creek "was impure and turbid...on account of receiving the sewage from the city..." Shepard (p. 30). Shepard (p. 41) also noted that the smaller streams in the Burlington and Keokuk Limestones frequently disappear, finding "underground channels for considerable distances before they again appear". As examples of interrupted streams, Shepard mentioned Wilson Creek and the south fork of Dry Sac. In recent years, urbanization and increased use of water by an expanding population have intensified troublesome waste-disposal problems in the karst environment especially in the Wilson Creek basin. Some of these problems have been documented by Harvey and Skelton (1968, p. C217-C220). Recommendations for the correction of the problems were made by the Federal Water Pollution Control Administration in 1969.

Detailed geologic maps have been published for two quadrangles in the area (Beveridge, 1970; Fellows, 1970). Both maps show areas where streamflow losses occur.

WELL-LOCATION SYSTEM

Locations of the wells cited in this report are given in accordance with the General Land Office Survey system in this order: township, range, section, quarter section, quarter-quarter section, and quarter-quarter-quarter section (10-acre tract). The subdivisions of a section are designated a, b, c, and d in counterclockwise direction beginning in the northeast quarter. If several wells are in a 10-acre tract, they are numbered serially after the above letters, and in the order in which they were inventoried (fig. 2).

The directions of townships and ranges are not used in numbering wells since all townships in the report area are north of the base line and all ranges are west of the principal meridian.

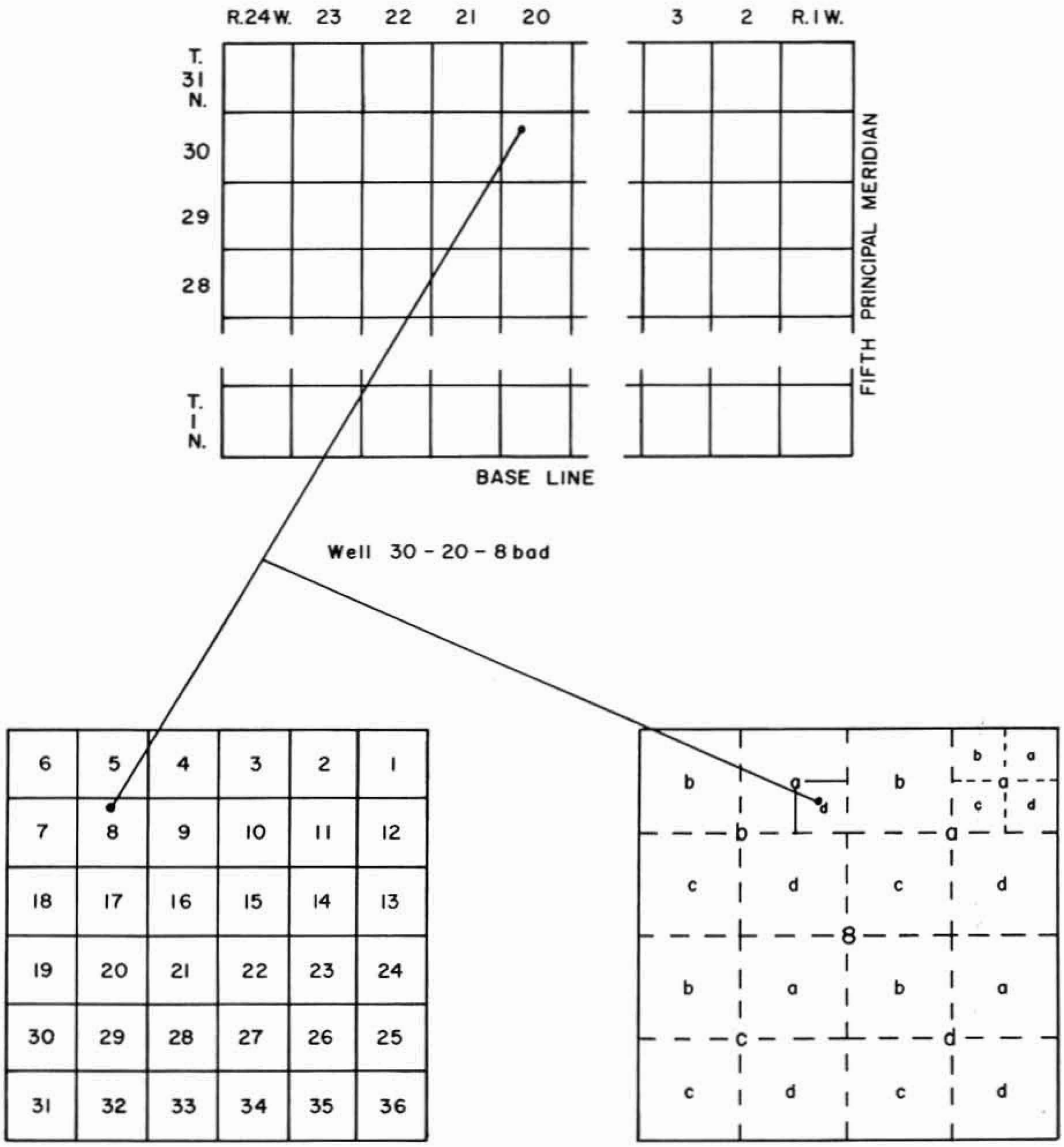


Figure 2

Diagram of well-location system.

ACKNOWLEDGMENTS

The authors are indebted to many people who provided information or help in collecting data. Appreciation is expressed to Dr. William C. Hayes, environmental geologist, City of Springfield; the City Utilities of Springfield; the managers of industrial plants; water superintendents of the towns in the area; and the individual well owners. Special thanks are due the drilling contractors who supplied the Missouri Division of Geology and Land Survey with well data which are the basis of its extensive well-log files, which the authors used.

GEOGRAPHIC SETTING

The study area lies within the Springfield-Salem Plateaus section of the Ozark Plateaus physiographic province, Interior Highlands division as defined by Fenneman (1946).

The Springfield Plateau is underlain by rocks of Mississippian age and is slightly higher in elevation than the Salem Plateau which is underlain by rocks of Ordovician age. The division between the two plateaus has been termed the Eureka Springs Escarpment (fig. 3).

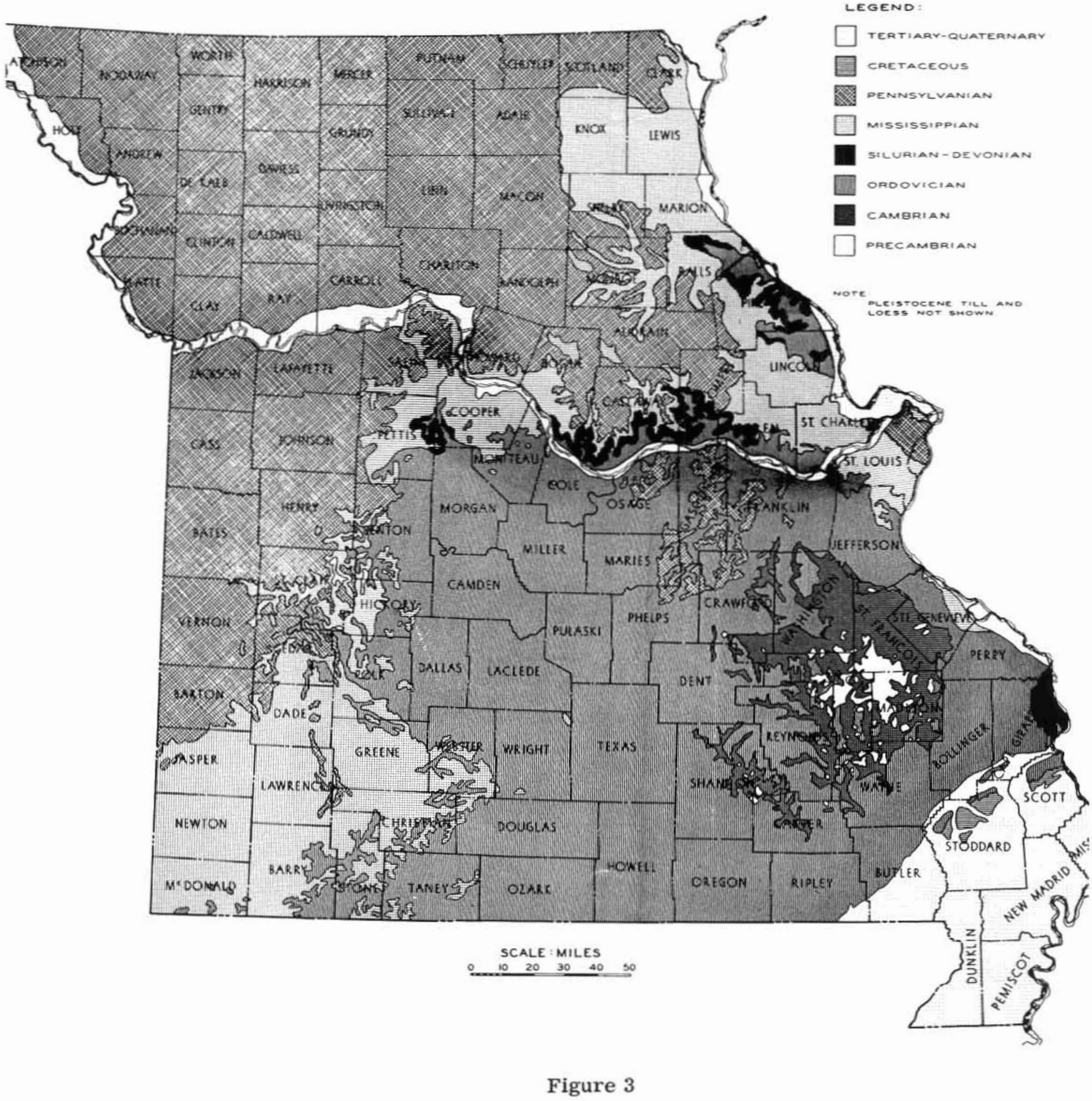


Figure 3

Generalized geologic map of Missouri.

TOPOGRAPHY

The study area is in a topographic saddle with high remnants of the Salem Plateau on the east and the Springfield Plateau on the west standing at elevations of more than 1,400 feet above sea level. Much of the area is 1,200 to 1,300 feet above sea level. The terrain is gently rolling in the divide areas with moderate relief along the rivers. Sinkholes are a prominent feature of the topography. The elevation of the divide areas ranges from 1,350 to 1,450 feet above sea level. Total relief in the area is about 300 feet.

Modern $7\frac{1}{2}$-minute topographic maps are available for the entire study area (fig. 1).

DRAINAGE PATTERNS AND RELATED DRAINAGE PROBLEMS

The project area is located within two drainage basins--the Sac River basin in the northern part of the area and the James River basin in the southern part; therefore, all runoff eventually reaches one of the rivers through the network of tributary streams shown on plate 1. Springfield is located on the drainage divide between the two basins, with approximately half of the city in each of the basins. The city utilizes stream impoundments and springs in the Sac River basin for most of its domestic water supply. A substantial part of this water is then discharged to the James River via the Southwest Sewage Treatment plant in Wilson Creek. Thus, the city is augmenting flows in the James River basin with water from an adjacent basin, currently (1976) about 12 to 15 Mgal/d.

The major streams in the area are sustained during low-flow periods by outflow of ground water from natural underground reservoirs in the soluble carbonate rocks. These streams represent the base level toward which much of the shallow ground water moves. However, the flow patterns of a number of small tributary streams are affected by the underground solution cavities during low-flow periods, resulting in water losses to bedrock and interrupted flow in the streams (see section entitled "Seepage-Run Information"). The uneven distribution of permeability beneath these karst streams causes them to lose or gain water, depending on the position of the water table with reference to streambed elevations. The streams may lose part of their flow or disappear entirely where

the underlying rock is very permeable, and they may gain water where the rock is less permeable and the water table is above stream level.

Because some of the small tributary streams are interrupted during dry seasons and some lose part of their flow to bedrock during all seasons, the safe disposal of treated wastes can pose problems. In addition to the problem of poor aeration in the ground, any polluted water in the subsurface reach of these karst streams might be easily drawn toward pumping wells. At present (1976), South Dry Sac Creek and Wilson Creek are the receiving streams for treated wastes; significant water loss to bedrock was not observed to be a problem below the points where treated sewage effluent enters these streams.

CLIMATE

The study area has a humid climate with relatively mild winters and warm summers. The annual average temperature is 13.3° Celsius or 56.2° Fahrenheit. The average for July (the hottest month) is 25.4°C (77.8°F), and for January (the coldest month), 0.5°C (32.9°F). The average annual precipitation is 39.70 inches. Additional precipitation data are shown in table 2, compiled from National Weather Service records.

GROUND WATER

Industries, municipalities, public water-supply districts, subdivisions and rural home owners in the Springfield area are all dependent in some measure or other upon water from wells or springs. Since ground water is such a significant part of the water resource it is important that the water manager understands how the groundwater system operates.

Basic to the investigator attempting to understand how the groundwater system operates is the collection of data related to drilling water wells in the area. Such data include geologic logs of the wells, information on well construction, water levels, well yields, and drawdowns. Through the cooperation of well-drilling contractors, the Missouri Division of Geology and Land Survey

Table 2

AVERAGE AND EXTREME VALUES OF
PRECIPITATION OBSERVED AT SPRINGFIELD, MISSOURI

National Weather Service		Extreme Precipitation Values, 1877-1975 (in inches)	
Month	(1941-1970) Avg. No. Inches	Least	Most
Jan.	1.67	0.07 (1943)	9.31 (1916)
Feb.	2.22	0.35 (1947)	7.29 (1882)
March	2.99	0.50 (1956)	9.09 (1935)
April	4.27	0.86 (1955)	12.15 (1945)
May	4.93	0.34 (1911)	16.15 (1943)
June	4.72	0.58 (1952)	15.20 (1877)
July	3.62	0.33 (1953)	18.75 (1958)
Aug.	2.94	0.50 (1955)	10.81 (1915)
Sept.	4.11	0.05 (1928)	11.36 (1975)
Oct.	3.44	0.31 (1917)	11.94 (1919)
Nov.	2.34	0.14 (1910)	8.14 (1946)
Dec.	2.45	0.13 (1950)	11.02 (1895)
Year	39.70	25.21 (1953)	65.31 (1877)

collects such information on all public supply wells and many private wells. This information is kept on file at the Missouri Division of Geology and Land Survey. Table 3 presents this type of information for representative water wells in the Springfield area. Most of the wells listed in table 3 were visited during the course of this investigation and measurements were made of depths to water when possible. These data were the basis for constructing the potentiometric map in the section entitled "Movement of Ground Water". (See plate 3).

Table 3

RECORDS OF SELECTED WELLS IN THE SPRINGFIELD AREA

Geologic Formation: Є, Cambrian system; Єd, Davis Formation; Єdd, Derby Doerun Dolomite; Єe, Eminence Dolomite; Єp, Potosi Dolomite; M, Mississippian system; Mbk, Burlington-Keokuk Limestone; Mc, Compton Formation; Me, Elsey Formation; Mk, Kinderhookian Series; Mn, Northview Formation; Mo, Osagean Series; Mp, Pierson Formation; Mw, Warsaw Formation; O, Ordovician System; Oc, Cotter Dolomite; Og, Gasconade Dolomite; Ogu, Gunter Sandstone Member; Ojc, Jefferson City Dolomite; Or, Roubidoux Formation; pЄ, Precambrian rocks.

Map number (pl. 3)	Location	Quadrangle	Owner	Surface formation	Elevation land surface	Penetration basal formation: Formation	Penetration basal formation: Feet	Total depth (ft)	Static water level feet below land surface: Feet	Static water level: Date	Yield (gpm)	Draw-down (ft)	Specific capacity (gpm/ft of drawdown)	Time pumped (hrs.)	Casing record: Feet	Casing record: Formation	Casing record: Top	Casing record: Bottom	Northview Formation: Top	Northview Formation: Bottom	Mo. Geol. Survey number
									Wells that bottom in Potosi Dolomite or older rocks												
1	27-22-13cba4	Nixa	Standard Brands	Mbk	1,295	Єdd	20	1,640	232	4-10-74	390	23	17	4	450	Oc	265	455	240	250	27,673
2	a/ 28-21-20cdc	Nixa	Springfield (James River Power Plant)	Mbk	1,161	Єdd	5	1,520	34 30	6-8-56 3-7-73	1,385	58	24	--	284	Oc	190	365	165	175	14,584
3	28-21-29bbd	Nixa	Springfield (James River Power Plant)	Mbk	1,160	Єdd	5	1,530	--	--	--	--	--	--	297	Oc	205	370	175	190	20,910
4	a/ 28-22-3bcc1	Springfield	Dayton Rubber Co.	Mbk	1,279	Єdd	20	1,640	259 340-350	8-8-58 1968	1,140	52	22	--	436	Oc	325	515	298	312	13,363
5	28-22-7bbc	Brookline	Springfield (SW Power Plant)	Mbk	1,252	pЄ	67	2,190	--	--	--	--	--	--	446	Ojc	440	650	275	307	27,062
6	28-22-7bbd	Brookline	Springfield (SW Power Plant	Mbk	1,252	Єdd	110	1,650	205 186 194	1972 3-15-73 7-22-75	2,005	75	27	72	706	Or	665	840	260	277	27,070
7	28-22-11cbc1	Springfield	Springfield (Parkcrest Village)	Mbk	1,285	Єdd	10	1,605	198 214 226	1964 6-28-74 7-31-75	1,200 895	40 58	30 15	3 1,632	427	Oc	330	495	305	320	23,411
8	28-23-12aab	Brookline	Springfield (SW Power Plant)	Mbk	1,260	Єd	45	1,655	--	--	--	--	--	--	730	Or	635	825	265	280	--
9	29-21-22bdd1	Galloway	Hickory Hill Country Club	Mbk	1,360	Єdd	25	1,600	340 345	6- -59 3-22-73	584	--	--	--	400	Oc	250	425	205	235	18,160
10	29-21-29bdb1	Springfield	Kraft Food Co.	Mbk	1,341	Єdd	32	1,632	385 454	3-28-55 6-11-74	505	24	21	5	405	Oc	275	455	235	255	13,415
11	a/ 29-21-29ddb	Galloway	General Electric Plant	Mbk	1,347	Єdd	5	1,625	410	1-10-61	872	21	41	24	410	Oc	270	455	235	255	19,405
12	a/ 29-22-2	Ebenezer	Springfield (Fulbright Pump Station-CU No. 1)	Mbk	1,113	Єdd	54	1,404	85 79 57	1- -15 6-6-74 1-5-76	764 2,500	-- 179	-- 14	-- 56	--	--	--	--	100	150	2,551
13	a/ 29-22-34bbc1	Springfield	U.S. Medical Center	Mw	1,283	Єdd	35	1,675	268 325	7- -54 4-11-73	500	31	16	--	380	Oc	350	535	320	340	12,873
14	29-23-3dcc	Brookline	Villa Park Heights	Mbk	1,242	Єdd	15	1,475	224	1974	--	--	--	--	431	Ojc	405	600	217	238	27,104
15	30-22-25aba	Ebenezer	Springfield (CU No. 7)	Mo	1,130	Єdd	10	1,335	110 58 60	11- -54 9-16-68 9-21-68	703 650	89 75	8 9	--	312	Ojc	220	430	50	100	13,072
16	30-22-25bda1	Ebenezer	Springfield (CU No. 6)	Mo	1,139	Єdd	53	1,388	120 66 80	11- -54 9-16-68 1-5-76	759	109	7	--	327	Ojc	245	435	70	130	13,071
17	30-22-25cbc1	Ebenezer	Springfield (CU No. 4)	Mbk	1,136	Єdd	33	1,403	120 67 81	1954 9-16-68 1-5-76	955	54	18	--	315	Ojc	275	480	115	163	13,104
18	30-22-25cda	Ebenezer	Springfield (CU No. 5)	Mo	1,157	Єdd	26	1,401	133 86	11- -54 9-16-68	703 600	50 36	14 18	22 48	302	Ojc	280	480	110	165	13,106
19	30-22-26ada	Ebenezer	Springfield (CU No. 9)	Mo	1,127	Єdd	16	1,366	107 57 86 70	11- -54 9-16-68 6-6-74 1-6-76	703	15	47	--	252	Oc	150	260	105	140	13,105
									Wells that bottom in Eminence Dolomite												
20	27-21-5ddb	Ozark	Fremont Hills Country Club	Mbk	1,270	Єe	5	1,245	165 127	11- -70 7-25-73	-- --	--	--	--	440	Oc	260	445	--	--	26,660
21	27-21-22cbd	Ozark	City of Ozark No. 2	Mo	1,150	Єe	30	1,150	2 26	1- -65 3-17-71	980	20	49	--	291	Oc	120	295	93	110	23,454
22	27-21-22cca	Ozark	City of Ozark No. 3	Mo	1,140	Єe	14	1,137	F	7-22-65	250	--	--	--	291	Oc	115	310	88	100	23,697
23	27-21-26cdd	Ozark	City of Ozark No. 4	Mo	1,342	Єe	2	1,375	228 202	8- -71 6-4-74	--	--	--	--	450	Oc	332	530	300	318	26,932
24	a/ 27-22-13cba2	Nixa	Diversified Plastics	Mo	1,292	Єe	22	1,282	215	7-19-73	--	--	--	--	--	--	--	--	--	--	3,850
25	a/ 27-22-13cba3	Nixa	City of Nixa No. 2	Mo	1,292	Єe	12	1,284	190 234	6- -42 5-31-74	--	--	--	--	430	Oc	270	460	240	250	7,800

Table 3 (continued).....

Map number (pl. 3)	Location	Quadrangle	Owner	Surface formation	Elevation land surface	Penetration basal formation: Formation	Penetration basal formation: Feet	Total depth (ft)	Static water level feet below land surface: Feet	Static water level: Date	Yield (gpm)	Draw-down (ft)	Specific capacity (gpm/ft of drawdown)	Time pumped (hrs.)	Casing record: Feet	Casing record: Formation	Casing record: Top	Casing record: Bottom	Northview Formation: Top	Northview Formation: Bottom	Mo. Geol. Survey number
										Wells that bottom in Eminence Dolomite--Continued											
26	b/ 28-21-4bb1	Galloway	Lake Subdivision	Mbk	1,270	6e	30	1,205	185	7- -56	--	--	--	--	272	Oc	235	420	205	220	14,642
27	28-21-9bcd1	Galloway	Ash Grove Lime	Mbk	1,200	6e	27	1,137	80 126	7-24-51 1-28-75	525 450	50 30	10 15	6 4	400	Ojc	350	555	140	150	11,591
28	a/ 28-21-33cdd	Ozark	Cassidy Water Co.	Mo	1,313	6e	95	1,370	164	5-17-72	580	21	28	2	470	Oc	330	510	298	320	27,014
29	28-22-11dad	Springfield	Springfield (Parkcrest Village)	Mbk	1,273	6e	15	1,230	170 214	2- -57 9-6-74 1-22-75	400 550	-- 111	-- 5	-- 1,632	410	Oc	310	470	270	295	15,898
30	a/ 28-22-13acd1	Springfield	Twin Oaks Country Club	Mbk	1,252	6e	20	1,235	152 166	7- -56 6-20-74	165	25	6	--	325	Oc	300	455	250	255	14,663
31	a/ 28-22-35ddc	Nixa	Chalet City South	Mbk	1,260	6e	3	1,270	167	6-20-74	--	--	--	--	455	Oc	330	510	302	318	26,933
32	28-23-16aaa	Brookline	Chalet City Mobil Home Park	Mo	1,291	6e	27	1,172	213 193	7- -70 6-5-74	275	8	34	--	383	Oc	290	410	270	275	26,600
33	a/ 28-23-20caa	Republic	City of Republic No. 2	Mbk	1,303	6e	19	1,189	200	4- -55	242	5	48	1.5	350	Oc	290	420	265	275	13,428
34	29-19-6	Strafford	Buena Vista Ranch	Mo	1,500	6e	130	1,200	240	8- -71	1,000	260	4	--	126	Oc	110	285	45	95	26,882
35	29-20-4baa	Baseville	City of Strafford	Mo	1,481	6e	45	1,100	280 295	5- -68 5-14-73	200 130	182 110	1 1	--	500	Ojc	320	555	90	130	25,602
36	29-21-17bcc1	Springfield	Lily Tulip Cups	Mbk	1,340	6e	66	1,256	337 409	5-20-54 5- -72	440	27	16	24	422	Oc	270	450	240	255	12,653
37	29-21-20abd1	Springfield	Welsh Packing	Mo	1,350	6e	15	1,210	378	4- -57	200	--	--	--	--	--	--	--	225	255	16,014
38	29-21-20bab1	Springfield	Springfield Packing Co.	Mbk	1,320	6e	9	1,162	262	4- -42	250	--	--	--	400	Oc	235	410	205	225	7,746
39	29-21-22acb1	Galloway	Hickory Hills Country Club	Mbk	1,350	6e	135	1,295	235	7- -38	155+	--	--	--	320	Oc	230	395	155	215	4,916
40	29-21-25acd	Galloway	James R. Addition	Mbk	1,345	6e	10	1,165	265	6- -70	--	--	--	--	385	Ojc	375	595	170	200	26,611
41	b/ 29-22-2dcc1	Ebenezer	SW Rendering Co.	Mbk	1,186	6e	10	1,055	--	--	--	--	--	--	110	Mc	100	120	65	100	20,985
42	29-22-6cca	Brookline	Springfield (Airport)	Mbk	1,267	6e	80	1,250	218 258	8-7-45 3-16-73	307	53	6	24	450	Oc	275	450	235	265	8,718
43	a/ 29-22-6cdd	Brookline	Litton Industries	Mbk	1,280	6e	225	1,390	265 281	5- -64 5- -72	300	155	2	--	385	Oc	280	435	260	265	22,630
44	a/ 29-22-10dcb1	Springfield	Frisco RR	Mbk	1,298	6e	70	1,275	345	8-20-56	600	65	9	5	405	Oc	305	525	270	295	14,800
45	29-22-11dad1	Springfield	Producers Ice Co.	Mbk	1,334	6e	20	1,220	208 328	4-20-33 1-8-47	--	--	--	--	--	--	--	--	240	<285	2,719
46	29-22-11dbc1	Springfield	Selmier Peerless	Mbk	1,332	6e	40	1,255	335 397	1964 6-10-74	--	--	--	--	425	Oc	302	490	255	285	23,339
47	29-22-13ccc1	Springfield	Springfield Ice and Refrig.	Mbk	1,267	6e	10	1,210	228	12- -37	--	--	--	--	452	Ojc	370	665	--	--	4,561
48	b/ 29-22-13ccc2	Springfield	Smith Laundry	Mbk	1,267	6e	12	1,202	285	7- -48	105	15	7	--	390	Ojc	365	660	210	230	6,235
49	29-22-13ccc3	Springfield	Springfield Ice and Refrig.	Mbk	1,275	6e	7	1,212	231	3- -37	300	18	16	--	320	Oc	255	490	225	240	4,135
50	a/ 29-22-14ddc1	Springfield	Empire Food	Mbk	1,286	63	11	1,231	334	3- -47	--	--	--	--	454	Ojc	390	680	235	250	9,459
51	29-22-14ddd3	Springfield	R. R. Zerr	Mbk	1,270	6e	11	1,211	339	11- -46	250	17	14+	--	388	Oc	245	455	215	240	9,307
52	29-22-14ddd4	Springfield	Springfield (Gas and Elec. Co.)	Mbk	1,267	6e	13	1,223	238 418	2- -39 1-3-75	592	135	4+	--	450	Oc	270	465	222	250	5,269
53	29-22-15ddd	Springfield	Paul Mueller Co.	Mbk	1,290	6e	25	1,250	420 450	1-7-72 6-10-74	225	27	8	8	496	Ojc	495	--	260	283	27,005
54	b/ 29-22-16ddd1	Springfield	W. Schaffitzel	--	1,270	6e	240	1,515	300	11- -38	300	--	--	--	312	Mc	298	314	280	298	5,411
55	29-22-20bac1	Springfield	Springfield (Orchard-crest)	Mbk	1,258	6e	11	1,216	233 276	1954 9-6-74 1-22-75	350 117	17 26	20 5	-- 576	389	Oc	290	460	257	276	12,699
56	29-22-24aba	Springfield	Tri-State Laundry	Mo	1,320	6e	8	1,248	405 452	1-20-71 6-19-74	180	17	11	4	455	Oc	275	510	245	263	26,723
57	29-22-24bbc1	Springfield	Kresgee-Co.	--	1,308	6e	21	1,251	365	11- -37	--	--	--	--	310	Oc	280	505	245	270	4,568

a/ Chemical analysis in Table 5.
b/ Not field inventoried.

Table 3 (continued).....

Geologic Formation: Є, Cambrian system; Єd, Davis Formation; Єdd, Derby Doerun Dolomite; Єe, Eminence Dolomite; Єp, Potosi Dolomite; M, Mississippian system; Mbk, Burlington-Keokuk Limestone; Mc, Compton Formation; Me, Elsey Formation; Mk, Kinderhookian Series; Mn, Northview Formation; Mo, Osagean Series; Mp, Pierson Formation; Mw, Warsaw Formation; O, Ordovician System; Oc, Cotter Dolomite; Og, Gasconade Dolomite; Ogu, Gunter Sandstone Member; Ojc, Jefferson City Dolomite; Or, Roubidoux Formation; pЄ, Precambrian rocks.

Map number (pl. 3)	Location	Quadrangle	Owner	Surface formation	Elevation land surface	Penetration basal formation		Total depth (ft)	Static water level feet below land surface		Yield (gpm)	Draw-down (ft)	Specific capacity (gpm/ft of drawdown)	Time pumped (hrs.)	Casing record				Northview Formation		Mo. Geol. Survey number
						Forma-tion	Feet		Feet	Date					Feet	Forma-tion	Top	Bottom	Top	Bottom	
Wells that bottom in Eminence Dolomite--continued																					
58	a/ 29-22-27cab1	Springfield	Syntex Inc.	Mbk	1,212	Єe	5	1,240	285	1-26-71	--	--	--	--	152	Mbk	0	160	270	290	13,074
59	29-22-34bda1	Springfield	U.S. Medical Center	Mw	1,286	Єe	21	1,321	202 226 243 246 254 338	6- -36 1943 1949 1950 10- -51 4-11-73	203 180	11.5 13.9	17 13	--	270	Mo	40	320	320	350	3,716
60	30-23-21aac	Willard	Willard Country Club	Mbk	1,201	Єe	10	1,105	184	--	--	--	--	--	385	Ojc	380	605	290	328	25,644
Wells that bottom in Gunter Member																					
61	27-23-20bdd	Republic	City of Clever	Mo	1,396	Ogu	45	1,300	236 240 250	8- -64 6-5-74 1-16-75	200 185	9 10	22 19	-- 1	405	Oc	280	530	265	270	22,871
62	a/ 28-22-7aaa1	Springfield	Springfield (SW Sewage Treatment Plant)	Mbk	1,150	Ogu	35	1,080	39 90 108	6-10-58 6-5-74 1-30-75	252 200	44 10	6 20	-- 2	313	Oc	182	325	151	170	17,185
63	a/ 28-22-20cab1	Nixa	Green County PWSD No. 1 (Battlefield)	Mbk	1,263	Ogu	50	1,225	180 188 196 218	1965 3-8-73 6-4-74 1-17-75	340 230	9 6	38 38	-- 2	503	Ojc	480	685	310	320	24,119
64	29-21-6	Ebenezer	Springfield Municipal Recreation Center	Mbk	1,283	Ogu	44	1,139	270	--	130	--	--	--	210	Oc	180	395	130	180	11,782
65	b/ 29-22-2	Ebenezer	Central Bible College	Mbk	1,259	Ogu	73	1,218	280	9- -40	100	2	50	--	--	--	--	--	180	210	6,332
66	b/ 29-22-11dca1	Springfield	A. White Const. Co.	Mbk	1,325	Ogu	45	1,215	150	5- -34	130	--	--	--	27	Mbk	0	140	240	270	2,863 8,052
67	29-22-13bcc1	Springfield	Springfield Laundry	Mw	1,300	Ogu	36	1,346	283	6- -37	150	--	--	--	71	Mbk	45	205	325	340	4,334
68	29-22-14bca1	Springfield	Pepsi-Cola Bottling Co.	Mbk	1,298	Ogu	35	1,225	357	1967	150	12	12	--	430	Oc	305	535	275	292	24,393
69	29-22-14dcc	Springfield	Mid-America Dairy	Mbk	1,280	Ogu	34	1,209	303	4- -38	440	54	8	--	448	Oc	266	470	230	250	4,701
70	29-22-14ddd2	Springfield	Mid-America Dairy	Mbk	1,274	Ogu	35	1,205	225	4- -35	300	--	--	--	300	Oc	266	470	225	245	3,193
71	29-22-24bba2	Springfield	Gillioz Theater	Mbk	1,302	Ogu	30	1,240	300	8- -38	--	--	--	--	275	Mc	260	275	240	260	4,972
72	30-23-26aba1	Willard	City of Willard	Mbk	1,240	Ogu	45	1,130	178 210	5- -61 6-6 74	167	--	--	--	380	Oc	350	415	300	330	19,701
Wells that bottom in Gasconade Dolomite																					
73	a/ 28-19-19aca	Rogersville	City of Rogersville	Mbk	1,485	Og	360	1,260	200	5-30-74	--	--	--	--	175	Oc	150	505	125	135	12,589
74	b/ 28-21-3acb	Galloway	L. Lee	Mbk	1,316	Og	15 •	800	287	--	--	--	--	--	101	Mbk	5	110	200	215	15,999
75	28-21-6caa1	Springfield	SW Bell Telephone Co.	Mbk	1,316	Og	132	1,002	240 258	10- -57 6-11-74	100	14.5	7	--	327	Oc	315	695	295	305	16,699
76	28-21-9aab1	Galloway	Sequiota School	Mbk	1,299	Og	20	850	220	4- -64	--	--	--	--	361	Oc	255	445	225	245	22,582
77	a/ 28-23-20cbb1	Republic	City of Republic No. 1	Mbk	1,305	Og	135	1,000	165 216	1926 6-5-74	125	12	10	--	300	Mk	--	305	--	--	2,111
78	29-20-4aab1	Strafford	E. McNeese	Mo	1,478	Og	40	715	170 275	1959 4-4-74	15	140	0.1	--	32	Mo	0	85	85	130	17,986
79	b/ 29-20-5ccd1	Galloway	Okino Dairy	Mo	1,330	Og	83	723	120	2- -41	50	--	--	--	116	Oc	100	270	50	90	6,778
80	29-21-3	Bassville	Jones Farm	Mo (est)	1,342	Og	128	868	265 347 361	6- -39 10-19-72 5-29-74	--	--	--	--	310	Oc	145 (est)	355	95 (est)	145 (est)	5,400
81	b/ 29-21-30aab1	Springfield	K. Wills	Mbk	1,337	Og	21	836	355	7- -40	--	--	--	--	64	Mbk	0	135	255	250	6,237
82	b/ 29-22-12cca1	Springfield	Green City Wood Works	Mbk	1,338	Og	70	900	320	9- -40	10	--	--	--	180	Mo	145	255	255	277	6,483
83	b/ 29-22-15dda1	Springfield	I. Brinkman	Mbk	1,305	Og	67	907	285	11- -39	285	--	--	--	27	Mbk	0	160	255	270	5,839
84	29-22-24bca1	Springfield	Landers Theater	Mbk	1,315	Og	56	901	240 419	6- -37 3-8-74	200	--	--	--	325	Oc	305	485	265	285	4,296

Table 3 (continued).....

Map number (pl. 3)	Location	Quadrangle	Owner	Surface formation	Elevation land surface	Penetration basal formation: Formation	Penetration basal formation: Feet	Total depth (ft)	Static water level feet below land surface: Feet	Static water level: Date	Yield (gpm)	Drawdown (ft)	Specific capacity (gpm/ft of drawdown)	Time pumped (hrs.)	Casing record: Feet	Casing record: Formation	Casing record: Top	Casing record: Bottom	Northview Formation: Top	Northview Formation: Bottom	Mo. Geol. Survey number
								Wells that bottom in Gasconade Dolomite--continued													
85	29-22-24dd	Springfield	SMSU	Mbk	1,318	Og	160	1,000	178	3- -14	66	--	--	--	318	Oc	276	475	245	276	1,886
86	a/ 30-20-17acb	Bassville	Acres of Shade Trailer Park	Mo	1,380	Og	140	729	290 283	1969 5-28-74	105	10	10	4	356	Ojc	250	460	45	100	26,506
87	b/ 30-22-20dddl	Ebenezer	Dogwood Trails	Mbk	1,082	Og	30	700	70	6- -57	36	--	--	--	200	Oc	170	250	125	165	16,797
								Wells that bottom in the Roubidoux Formation													
88	a/ 28-20-8aadl	Galloway	Logan Elementary School R8	Mbk	1,426	Or	108	758	181	5- -56	20	7	3	--	257	Oc	245	420	205	225	14,464
89	a/ 28-20-15bcdl	Oak Grove Heights	Logan Rogersville High School	Mo	1,422	Or	25	685	240 129 176	1967 5-17-73 5-30-74	60	--	--	--	350	Oc	160	445	135	150	25,206
90	b/ 28-21-3cad	Galloway	B. T. Wood	Mbk	1,302	Or	47	692	204	1- -51	10	3.5	3	--	215	Mn	210	220	--	--	--
91	28-21-3dcdl	Galloway	W. Johnson	Mo	1,230	Or	150	750	116 120	2-5-73 5-30-74	--	--	--	--	158	Mc	150	165	130	150	21,001
92	28-21-4cabl	Galloway	Springfield Disposal	Mbk	1,219	Or	196	771	142	10- -60	87	18	5	--	197	Oc	190	370	155	175	19,273
93	a/ 28-21-4ccc	Galloway	Valley Park Subdivision	Mo	1,290	Or	35	685	--	--	100	--	--	--	403	Oc	280	403	238	257	25,801
94	28-21-7cdd	Springfield	Kickapoo School	Mbk	1,295	Or	35	700	185	3- -53	30	20	1	--	327	Oc	305	460	273	290	12,269
95	a/ 28-21-9bdb	Galloway	Sequiota Park	Mo	1,194	Or	90	630	96	7- -57	26	54	0.5	--	200	Oc	160	335	125	145	16,313
96	b/ 28-21-9dbdl	Galloway	A. Satts	Mbk	1,286	Or	45	685	125	1966	--	--	--	--	402	Oc	265	420	218	240	24,862
97	28-21-9dcdl	Galloway	Hooper Haven	Mbk	1,261	Or	40	650	158	5- -63	--	--	--	--	350	Oc	215	390	195	210	21,708
98	b/ 28-21-10acal	Galloway	M. Henslee	Mp	1,169	Or	8	523	50	3- -64	44	--	--	--	218	Oc	105	285	70	87	22,761
99	28-22-24bdc	Nixa	Cherokee School	Mbk	1,287	Or	195	875	193	5-31-74	--	--	--	--	350	Oc	320	470	298	305	19,207
100	28-23-30addl	Republic	Modern Tractor	Mbk	1,320	Or	125	755	215	9- -60	125	9	14	--	400	Oc	295	435	275	285	20,370
101	b/ 29-20-8aabl	Galloway	J. Mckerall	--	1,416	Or	65	625	198	4- -41	8	--	--	--	--	--	--	--	--	--	7,298
102	29-29-19ddb	Galloway	Pat Stafford	Mo	1,321	Or	20	580	230 236	4-11-73 5-30-74	--	--	--	--	290	Oc	165	340	130	145	26,548
103	29-21-1	Galloway	Roadway Express	Mo	1,410	Or	15	625	270	4-12-74	24	--	--	--	450	Ojc	405	610	93	130	--
104	29-21-4	Bassville	L. Brown	Mo	1,306	Or	45	575	250	3- -55	10	70	0.14	--	34	Mo	0	60	60	95	14,095
105	29-21-4	Bassville	C. Dulin	Mo	1,247	Or	17	527	365	5- 53	2	--	--	--	424	Ojc (est)	310 (est)	510 (est)	70 (est)	110 (est)	12,578
106	29-21-4cdd	Galloway	B. Lurvey	Mbk	1,390	Or	57	697	385	5- -55	12	9	1	--	24	Mbk	0	105	210	235	13,822
107	29-21-9abc	Galloway	G. Sill	Mo	1,390	--	--	760	390 400	12-11-63 5-1-74	100	--	--	--	280	--	--	--	--	--	--
108	29-21-10dbcl	Galloway	E. Lecompte	Mo	1,374	Or	63	683	200	3- -37	10	--	--	--	--	--	--	--	145	200	4,158
109	29-21-11dda	Galloway	Gibson Dairy	Mo	1,400	Or	151	746	330 371	1- -47 5-30-74	15	--	--	--	233	Oc	215	300	170	200	9,624
110	29-21-15ccl	Galloway	School Dist. 9 (Hickory Hills)	Mbk	1,381	Or	55	700	335	1952	--	--	--	--	310	Oc	275	430	220	255	11,959
111	29-21-16bbl	Galloway	KOLR TV	Mo	1,386	Or	25	675	335	8- -41	10	--	--	--	--	--	--	--	720	275	7,627
112	29-21-17dcdl	Galloway	Campbell Express	Mo	1,342	Or	35	670	348 361 363	6- -58 2-21-73 5-30-74	15	--	--	--	--	--	--	--	235	265	17,602
113	29-21-19bdbl	Springfield	B. Harrison	Mbk	1,327	Or	86	751	285	11- -36	165	--	--	--	100	Mbk	0	100	210	235	3,965
114	29-21-22dbb	Galloway	Suttles Trailer Park	Mbk	1,355	Or	135	755	--	--	--	--	--	--	--	--	--	--	--	--	--
115	b/ 29-21-27bcdl	Galloway	--	Mbk	1,326	Or	80	745	344	3- -58	12	--	--	--	38	Mbk	0	115	225	245	17,298

a/ Chemical analysis in Table 5.
b/ Not field inventoried.

Table 3 (continued).....

Geologic Formation: Є, Cambrian system; Єd, Davis Formation; Єdd, Derby Doerun Dolomite; Єe, Eminence Dolomite; Єp, Potosi Dolomite; M, Mississippian system; Mbk, Burlington-Keokuk Limestone; Mc, Compton Formation; Me, Elsey Formation; Mk, Kinderhookian Series; Mn, Northview Formation; Mo, Osagean Series; Mp, Pierson Formation; Mw, Warsaw Formation; O, Ordovician System; Oc, Cotter Dolomite; Og, Gasconade Dolomite; Ogu, Gunter Sandstone Member; Ojc, Jefferson City Dolomite; Or, Roubidoux Formation; pЄ, Precambrian rocks.

Map number (pl. 3)	Location	Quadrangle	Owner	Surface formation	Elevation land surface	Penetration basal formation: Formation	Penetration basal formation: Feet	Total depth (ft)	Static water level feet below land surface: Feet	Static water level feet below land surface: Date	Yield (gpm)	Drawdown (ft)	Specific capacity (gpm/ft of drawdown)	Time pumped (hrs.)	Casing record: Feet	Casing record: Formation	Casing record: Top	Casing record: Bottom	Northview Formation: Top	Northview Formation: Bottom	Mo. Geol. Survey number
								Wells that bottom in the Roubidoux Formation--continued													
116	a/ 29-21-34dcd1	Galloway	V. L. Stokes (Ridgeview Terrace Subdivision)	Mo	1,335	Or	170	800	355 361	5-17-73 3-10-74	--	--	--	--	500	Ojc	420	630	205	230	27,168
117	29-22-5	Springfield	Country Squire Village	Mbk	1,270	Or	165	785	231	11- -68	--	--	--	--	402	Oc	225	435	140	180	25,805
118	29-22-8ccb1	Springfield	Willard School	Mbk	1,299	Or	165	850	190 277	9- -64 6-10-74	20	--	--	--	390	Oc	300	470	270	295	23,337
119	29-22-8cac	Springfield	C. & H. Estates	Mbk	1,310	Or	145	840	190 291	3- -60 2-13-74	--	--	--	--	23	Mbk	0	165	280	305	19,844
120	29-22-16acb1	Springfield	New Bissett School	Mbk	1,290	Or	125	825	285 312	1- -50 6-10-74	20	--	--	--	422	Oc	295	485	255	275	11,381
121	29-22-17dcc	Springfield	Springfield City Utilities	Mbk	1,262	Or	--	748	281	2-15-73	--	--	--	--	306	Oc	--	--	--	--	--
122	29-22-17dcd1	Springfield	Candelight Trailer Park	Mbk	1,254	Or	25	700	165 275	9- -67 3-15-73	100	--	--	--	380	Oc	283	450	252	277	24,089
123	29-22-20baa1	Springfield	F. Lilley	Mbk	1,246	Or	150	800	-- 259	7- -59 1-31-74	22	--	--	--	282	Oc	275	450	245	260	18,272
124	b/ 29-22-23bdd1	Springfield	Pioneer Floral	Mbk	1,295	Or	165	900	260	7- -36	63	--	--	--	17	Mbk	0	175	290	310	3,685
125	b/ 29-22-24abc1	Springfield	Kentwood Hotel	Mo	1,331	Og	5	875	430	7- -54	--	--	--	--	36	Mo	0	290	290	330	12,928
126	29-22-27dbb	Springfield	Leduc Packing	Mw	1,246	Or	118	903	304	5- -58	60	--	--	--	463	Oc	350	565	320	335	17,188
127	29-23-3dbc1	Willard	Rex Jones	Mbk	1,255	Or	105	700	200 219	-- 6-6-74	225	--	--	--	380	Oc	250	410	210	235	26,632
128	29-23-24aca1	Brookline	Travelers Trailer Park	Mbk	1,280	Or	35	715	175 259 257	5- -71 3-21-73 6-5-74	30 --	--	--	--	425	Oc	310	460	280	305	27,073
129	30-20-35cca1	Strafford	Callison Motel	Mo	1,495	Or	30	570	277 279	1960 5-29-74	--	--	--	--	228	Oc	130	335	85	120	19,381
130	30-21-28acc1	Bassville	Pleasant View School	Mbk	1,321	Or	40	650	260 267	8- -53 5-29-74	24	8	3	--	238	Oc	225	375	160	210	12,428
131	30-21-30ddb	Ebenezer	SW Bell Telephone Co.	Mbk	1,269	Or	95	700	203 232	3-20-68 6-6-74	--	--	--	--	310	Oc	240	390	180	225	25,968
132	30-22-25cbc2	Ebenezer	Springfield	Mbk	1,136	Or	10	500	81	1-5-76	--	--	--	--	275	Oc	175	275	120	160	27,609
								Wells that bottom in Jefferson City Dolomite													
133	27-209cda	Ozark	Christ Episcopal Church (Springfield)	Mo	1,265	Ojc	195	550	110 110	5- -46 9-20-73	--	--	--	--	221	Oc	140	355	110	125	9,173
134	28-20-8abb	Galloway	Crossroads Subdivision	Mr	1,382	Ojc	70	465	216 231	4-11-73 4-30-74	--	--	--	--	375	Oc	210	395	175	195	27,059
135	28-21-20acb	Nixa	C.U. Recreation (L. Springfield)	Mbk	1,225	Ojc	40	455	110 93	9-9-70 3-7-73	28	--	--	--	386	Oc	245	415	215	230	26,830
136	28-21-20bcc	Nixa	C.U. Recreation (L. Springfield)	Mbk	1,249	Ojc	35	480	100 126 125	3-18-60 3-7-73 5-30-74	24	--	--	--	350	Oc	281	445	248	262	18,906
137	a/ 28-21-21bdd	Ozark	J. Sacks	Mbk	1,260	Ojc	--	600	--	--	--	--	--	--	370	--	--	--	--	--	--
138	a/ 28-21-21dbb	Ozark	H. Cassey	Mbk	1,295	Ojc	--	505	--	--	--	--	--	--	280.	--	--	--	--	--	--
139	28-22-6bba	Brookline	Briarwood Estates	Mbk	1,255	Ojc	150	580	230	1- -73	100	--	--	--	400	Oc	282	430	265	--	27,263
140	28-22-22bdd1	Nixa	T. Love	Mo	1,193	Ojc	58	463	115 123 117	1960 7-20-73 5-31-74	15	--	--	--	10	Mo	0	210	210	225	19,738
141	a/ 28-23-1abb	Brookline	Datema Wood Products	Mbk	1,262	Ojc	--	510	--	--	--	--	--	--	205	--	--	--	--	--	--
142	a/ 28-23-1bdd	Brookline	Whispering Lanes Trailer Park	Mbk	1,250	Ojc	20	450	230 216 216	4-11-73 8-23-73 6-11-74	--	--	--	--	348	Oc	285	430	240	255	21,343

Table 3 (continued).....

Map number (pl. 3)	Location	Quadrangle	Owner	Surface formation	Elevation land surface	Penetration basal formation: Formation	Penetration basal formation: Feet	Total depth (ft)	Static water level feet below land surface: Feet	Static water level: Date	Yield (gpm)	Draw-down (ft)	Specific capacity (gpm/ft of drawdown)	Time pumped (hrs.)	Casing record: Feet	Casing record: Formation	Casing record: Top	Casing record: Bottom	Northview Formation: Top	Northview Formation: Bottom	Mo. Geol. Survey number
								Wells that bottom in Jefferson City Dolomite--continued													
143	a/ 28-23-10acd	Brookline	Mr. Todhunter	Mbk	1,250	Ojc	--	450	--	--	--	--	--	--	25	--	--	--	--	--	--
144	28-23-15ccb	Brookline	Mrs. A. Rankin	Mbk	1,285	Ojc	115	550	166	--	--	--	--	--	325	Oc	293	435	280	285	24,115
145	a/ 28-23-17ada	Brookline	John Sparkman	Mbk	1,292	Ojc	--	528	--	--	--	--	--	--	--	--	--	--	--	--	--
146	a/ 28-23-23cba	Republic	U.S. National Park Service	Mbk	1,230	Ojc	143	550	129 130	7-11-73 6-5-74	--	--	--	--	300	Oc	250	407	227	235	23,756
147	a/ 28-23-25bdd	Republic	U.S. National Park Service	Mbk	1,190	Ojc	145	525	102	10-17-73	60	100	0.6	24	350	Oc	210	380	185	193	27,407
148	29-19-5a--	Strafford	S. Stroud	Mo	1,474	Ojc	64	359	160 216 212	5-15-58 11-13-73 5-29-74	--	--	--	--	33	Mn	--	77	--	77	17,295
149	29-20-3c	Oak Grove Heights	W. J. Dougherty	Mo	1,452	Ojc	76	401	235 223	6-5-61 4-5-74	--	--	--	--	67	Mo	0	100	100	135	20,159
150	29-20-11bbb	Oak Grove Heights	R. Patterson	Mo	1,463	Ojc	17	352	227 225	12-15-73 5-29-74	--	--	--	--	39	Mo	0	90	90	135	21,859
151	29-20-13ddd	Oak Grove Heights	Buena Vista Ranch	Oc	1,270	Ojc	46	246	48 57 52	7- -62 11-14-73 5-29-74	--	--	--	--	26	Oc	0	200	--	--	21,261
152	29-20-22bbb	Oak Grove Heights	A. Foley	Mp	1,377	Ojc	185	490	260 272 271	6- -61 12-3-73 5-29-74	--	--	--	--	59	Mp	0	65	65	95	20,208
153	29-21-4	Bassville	Mrs. S. Johnson	Mo	1,310	Ojc	126	486	282 339 335	7- -51 10-19-72 5-29-74	20	--	--	--	23	Mo	0	90	90	125	11,836
154	29-21-5	Springfield	E. Wilhite	Mbk	1,325	Ojc	25	440	354	11-9-72	15	--	--	--	27	Mbk	0	75	167	200	18,591
155	a/ 29-21-10aaa	Galloway	Bells Motor Court	Mbk	1,382	Ojc	15	395	340 367	6- -46 1-17-73	10	--	--	--	21	Mbk	0	55	145	180	9,208
156	a/ 29-22-18dcd	Springfield	Seven Gables Truck Stop	Mbk	1,281	Ojc	140	640	186 281	5- -64 3-15-73	130	--	--	--	415	Oc	315	500	292	315	23,057
157	29-22-20bab	Springfield	F. C. Lilley	Mbk	1,244	Ojc	70	500	230 262	2- -54 1-31-74	--	--	--	--	155	Me	125	--	245	252	12,729
158	29-22-32dca	Springfield	Southwest Village	Mbk	1,262	Ojc	145	640	200 255	1-6-70 3-15-73	100	--	--	--	434	Oc	325	495	292	310	26,517
159	a/ 29-23-15baa	Brookline	M. Batson	Mbk	1,260	Ojc	--	455	--	--	--	--	--	--	157	--	--	--	--	--	--
160	29-23-29cbb	Brookline	DX Service Station	Mo	1,231	Ojc	50	420	182 180	8-13-73 6-5-74	--	--	--	--	--	--	--	--	225	--	24,466
161	30-19-22dcc	Strafford	A. Stewart	Mo	1,481	Ojc	150	400	193 190	11-8-73 5-29-74	--	--	--	--	205	Oc	--	250	--	--	5,095
162	30-20-8bad	Bassville	Harry Boehme	Oc	1,252	Ojc	38	118	26 50	6- -46 10-12-72	7±	--	--	--	18	Oc	0	80	--	--	9,227
163	30-20-21abd	Bassville	G. W. Conway	Mn	1,393	Ojc	39	324	218 246 239	1- -52 10-13-72 5-28-74	9	--	--	--	40	Mn	0	100	0	100	12,144
164	a/ 30-21-1bbb	Bassville	R. D. Ryan	Mn	1,250	Ojc	--	305	--	--	--	--	--	--	22	--	--	--	--	--	--
165	a/ 30-21-2acb	Bassville	Little	Me	1,340	Ojc	--	320	--	--	--	--	--	--	20	--	--	--	--	--	--
166	a/ 30-21-2bda	Bassville	H. Crane	Me	1,345	Ojc	--	395	--	--	--	--	--	--	30	--	--	--	--	--	--
167	30-21-3abd	Bassville	T. C. Hart	Mo	1,307	Ojc	45	310	200 236 228	3- -48 10-11-72 5-28-74	5	--	--	--	44	Mn	40	105	40	105	10,076
168	a/ 30-21-3ddd	Bassville	Andrus	Mp	1,295	Ojc	--	500	--	--	--	--	--	--	90	--	--	--	--	--	--
169	30-21-27dad	Bassville	F. Taylor	Mo	1,326	Ojc	150	490	255 292 268	4- -59 10-12-72 5-29-74	10	--	--	--	26	Mo	0	120	120	185	18,705

a/ Chemical analysis in Table 5.

Table 3 (continued).....

Geologic Formation: Є, Cambrian system; Єd, Davis Formation; Єdd, Derby Doerun Dolomite; Єe, Eminence Dolomite; Єp, Potosi Dolomite; M, Mississippian system; Mbk, Burlington-Keokuk Limestone; Mc, Compton Formation; Me, Elsey Formation; Mk, Kinderhookian Series; Mn, Northview Formation; Mo, Osagean Series; Mp, Pierson Formation; Mw, Warsaw Formation; O, Ordovician System; Oc, Cotter Dolomite; Og, Gasconade Dolomite; Ogu, Gunter Sandstone Member; Ojc, Jefferson City Dolomite; Or, Roubidoux Formation; pЄ, Precambrian rocks.

Map number (pl. 3)	Location	Quadrangle	Owner	Surface formation	Elevation land surface	Penetration basal formation: Formation	Penetration basal formation: Feet	Total depth (ft)	Static water level feet below land surface: Feet	Static water level: Date	Yield (gpm)	Draw-down (ft)	Specific capacity (gpm/ft of drawdown)	Time pumped (hrs.)	Casing record: Feet	Casing record: Formation	Casing record: Top	Casing record: Bottom	Northview Formation: Top	Northview Formation: Bottom	Mo. Geol. Survey number
						Wells that bottom in Jefferson City Dolomite--continued															
170	a/ 31-21-35cbc	Bassville	Peace Chapel	Me	1,350	Ojc	--	300	--	--	--	--	--	--	50	--	--	--	--	--	--
171	a/ 31-21-36cca	Bassville	J. Delashmit	Me	1,336	Ojc	--	457	--	--	--	--	--	--	70	--	--	--	--	--	--
						Wells that bottom in Cotter Dolomite															
172	27-19-22bcc	Rogersville	M. Murphy	Mo	1,420	Oc	227	357	141 146	9-5-73 6-4-74	--	--	--	--	46	Mo	0	105	105	115	10,174
173	27-20-16caa	Ozark	G. Wernick	Mo	1,280	Oc	95	245	125 124 120	1- -47 9-20-73 6-4-74	--	--	--	--	24	Mo	0	120	120	140	9,675
174	27-20-25ddc	Rogersville	State Highway Department	Mbk	1,423	Oc	240	445	270 270	7- -61 9-13-73	--	--	--	--	167	Mp	155	175	175	190	20,160
175	27-20-32bba	Ozark	S. Rahm	Mo	1,360	Oc	165	425	175 223 221	4-9-49 7-26-73 6-4-74	--	--	--	--	--	--	--	--	230	245	6,538
176	a/ 27-21-3bba	Ozark	J. Taylor	Mbk	1,301	Oc	114	424	130 184	1- -41 8-7-73	--	--	--	--	19	Mbk	0	160	270	295	7,377
177	27-22-9bad	Nixa	J. Hires	Mbk	1,305	Oc	135	375	175 200 190	3- -56 7-20-73 5-31-74	--	--	--	--	43	Mbk	0	95	200	225	14,733
178	28-19-8bba	Oak Grove Heights	L. Stone	Mo	1,444	Oc	150	260	125 117	1- -60 5-1-74	-- --	--	--	--	59	Mo	0	75	75	97	19,528
179	28-19-31bbb	Rogersville	E. Brown	Mo	1,440	Oc	155	315	150 207 190	6-12-59 9-12-73 6-4-74	--	--	--	--	42	Mo	0	130	130	145	18,498
180	28-20-14cdd	Rogersville	E. E. Watson	Mbk	1,473	Oc	170	345	206 200	12-3-73 5-30-74	--	--	--	--	52	Me	50	85	150	165	19,136
181	28-20-26ddd	Rogersville	R. Crowe	Mo	1,445	Oc	165	355	150 221 200	12- -46 9-5-73 5-30-74	--	--	--	--	34	Mo	0	160	160	175	10,767
182	28-20-29ccc	Ozark	G. Nettell	Mbk	1,387	Oc	110	360	200 166	3- -62 7-25-73	--	--	--	--	24	Mo	0	215	215	230	20,789
183	28-20-29bbb	Ozark	Mr. Reese	Mbk	1,405	Oc	62	322	100 170	11- -46 5-30-74	--	--	--	--	50	Mbk	0	105	215	250	4,775
184	28-20-32bab	Ozark	--	Mbk	1,385	Oc	102	352	170	8-7-73	--	--	--	--	56	Mbk	0	100	>205	235	16,081
185	a/ 28-21-20ddb	Ozark	Ambler	Mbk	1,205	Oc	--	210	--	--	--	--	--	--	--	--	--	--	--	--	--
186	a/ 28-21-21ccd	Ozark	Day	Mbk	1,270	Oc	--	400	--	--	--	--	--	--	40	--	--	--	--	--	--
187	a/ 28-21-28aab	Ozark	Larimore	Mbk	1,285	Oc	* --	430	--	--	--	--	--	--	30	--	--	--	--	--	--
188	a/ 28-21-28adb	Ozark	Plank	Mbk	1,295	Oc	--	375	160	10-7-60	--	--	--	--	22	Mbk	0	145	260	280	19,384
189	28-21-36cbc	Ozark	C. C. Craker	Mbk	1,360	Oc	98	408	176 178	7-25-73 6-4-74	--	--	--	--	23	Mbk	0	160	280	295	20,449
190	28-22-23ada	Nixa	H. J. Bradford	Mbk	1,259	Oc	75	380	170 203	10- -59 7-20-73	--	--	--	--	24	Mbk	0	160	275	290	18,592
191	28-22-31bbb	Republic	H. W. Jones	Mbk	1,275	Oc	105	385	200	7-18-73	--	--	--	--	--	--	--	--	255	265	15,328
192	a/ 28-23-1cbb	Brookline	H. Simpson	Mbk	1,294	Oc	111	426	185 239	6- -62 9-19-73	--	--	--	--	20	Mbk	0	180	295	314	21,084
193	a/ 28-23-1cbc	Brookline	Ozark Structures	Mbk	1,285	Oc	115	420	--	--	--	--	--	--	--	--	--	--	--	--	--
194	28-23-3dda	Brookline	W. R. Raper	Mbk	1,278	Oc	30	360	85	12- -58	--	--	--	--	29	Mbk	0	180	305	315	17,905
195	a/ 28-23-10cca	Brookline	Eckles	Mbk	1,280	Oc	--	424	--	--	--	--	--	--	22	--	--	--	--	--	--
196	a/ 28-23-11ccc	Brookline	Thomas	Mbk	1,233	Oc	45	350	102	1- -62	--	--	--	--	80	Mbk	--	--	--	--	20,811

Table 3 (continued).....

Map number (pl. 3)	Location	Quadrangle	Owner	Surface formation	Elevation land surface	Penetration basal formation: Formation	Penetration basal formation: Feet	Total depth (ft)	Static water level feet below land surface: Feet	Static water level: Date	Yield (gpm)	Drawdown (ft)	Specific capacity (gpm/ft of drawdown)	Time pumped (hrs.)	Casing record: Feet	Casing record: Formation	Casing record: Top	Casing record: Bottom	Northview Formation: Top	Northview Formation: Bottom	Mo. Geol. Survey number
									Wells that bottom in Cotter Dolomite--continued												
197	a/ 28-23-14bbd	Brookline	Ghys	Mbk	1,215	Oc	--	425	--	--	--	--	--	--	100	--	--	--	--	--	--
198	28-23-18ccc	Brookline	G. Woods	Mbk	1,284	Oc	122	402	109	6- -58	--	--	--	--	23	Mbk	0	130	267	275	17,807
199	a/ 28-23-21abb	Brookline	Logan	Mbk	1,260	Oc	--	320	--	--	--	--	--	--	60	--	--	--	--	--	--
200	29-20-34bcc	Oak Grove Heights	J. C. Harp	Mo	1,390	Oc	127	282	178	11- -59	--	--	--	--	31	Mo	0	115	115	155	18,890
201	29-21-9cdc	Galloway	F. A. Mangan	Mo	1,390	Oc	--	425	338 411	10- -40 1-24-73	--	--	--	--	--	--	--	--	--	--	6,772
202	29-21-17aaa	Galloway	Downtown Airport	Mbk	1,370	Oc	145	400	351	2-27-73	--	--	--	--	28	Mbk	0	115	210	240	3,585
203	29-22-17ccc	Springfield	Sunset Drive-In Theater	Mbk	1,258	Oc	120	405	220 273	6- -50 1-25-74	--	--	--	--	33	Mbk	0	135	245	270	11,388
204	29-22-17daa	Springfield	J. Potter	Mo	1,260	Oc	110	400	245 226	12- -52 2-12-74	--	--	--	--	175	Mo	0	>255	<255	275	16,949
205	29-22-17dba	Springfield	K. Holton	Mbk	1,268	Oc	95	390	250 241	12- -56 2-12-74	--	--	--	--	59	Mbk	0	160	260	285	15,847
206	a/ 29-22-29cdd	Springfield	Chula Vista Trailer Park	Mbk	1,252	Oc	170	500	150 274	1966 4-11-73	100	--	--	--	425	Oc	330	500	302	323	24,401
207	a/ 29-23-9cdc	Brookline	Haney	Mbk	1,280	Oc	85	360	235 234 224	4- -58 8-28-73 6-5-74	--	--	--	--	24	Mbk	0	150	240	265	17,070
208	a/ 29-23-16bbc	Brookline	Anderson	Mbk	1,252	Oc	--	437	--	--	--	--	--	--	100	--	--	--	--	--	--
209	a/ 29-23-18acc	Brookline	R. Silverthorn	Mo	1,173	Oc	20	210	92 140	4- -48 8-14-73	--	--	--	--	30	Mo	0	160	160	175	10,089
210	30-20-10bcc	Bassville	Leona Wood	Oc	1,315	Oc	88	100	50 57	10- -46 10-12-72	6	--	--	--	12½	Oc	0	>100	--	--	9,567
211	a/ 30-21-3ada	Bassville	McWilliams	Me	1,340	--	--	150	--	--	--	--	--	--	20	--	--	--	--	--	--
									Wells that bottom in Mississippian Formations												
212	a/ 27-22-2aaa	Nixa	F. E. Weddington	Mbk	1,250	Me	15	175	125 123	9- -57 7-19-73	--	--	--	--	30	Mbk	0	160	--	--	16,916
213	a/ 27-23-5bac	Republic	R. G. Sims	Mo	1,191	Mr	--	88	25	7-18-73	--	--	--	--	21	Mo	0	--	--	--	20,804
214	a/ 27-23-18dbd	Republic	L. Little	Mo	1,368	Me	--	215	44 42	7-18-73 6-5-74	--	--	--	--	35	Mo	0	--	--	--	3,810
215	a/ 28-22-6bcb	Brookline	Henry	Mbk	1,210	Mbk	60	90	--	--	--	--	--	--	<30	Mbk	--	--	--	--	--
216	a/ 28-22-20cbc	Nixa	J. Hampton	Mbk	1,261	Mr	40	290	120 114 96	10- -61 7-20-73 5-31-74	--	--	--	--	--	--	--	--	--	--	--
217	a/ 28-23-3dad	Brookline	Potter	Mbk	1,275	Mbk	--	32	--	--	--	--	--	--	--	--	--	--	--	--	--
218	a/ 28-23-27aaa	Republic	B. McConnell	Mbk	1,250	Mc	21	266	117 117	7-18-73 6-5-74	--	--	--	--	10	Mbk	0	140	240	245	6,327
219	29-21-14dad	Galloway	W. C. Bates Jr.	Me	1,313	Mc	15	150	80 94 62	9- -62 2-27-73 5-30-74	30	--	--	--	20	Me	0	60	100	135	21,333
220	a/ 29-23-9ddd	Brookline	Mark	Mbk	1,264	Mbk	--	110	--	--	--	--	--	--	75	--	--	--	--	--	--
221	a/ 29-23-9ddd2	Brookline	Gibson	Mbk	1,282	Mbk	--	150	--	--	--	--	--	--	20	--	--	--	--	--	--
222	a/ 29-23-15acb	Brookline	MoVell	Mbk	1,275	Mbk	--	125	--	--	--	--	--	--	--	--	--	--	--	--	--
223	a/ 30-23-24aba	Willard	R. G. Shelton	Mbk	1,198	Mbk	149	149	100 56	5- -36 7-25-73	--	--	--	--	15	Mbk	0	--	--	--	3,608
224	a/ 31-23-33ddb	Willard	R. Forshee	Mbk	1,121	--	--	180	34	6-14-73	--	--	--	--	--	--	--	--	--	--	3,491

a/ Chemical analysis in Table 5.

DESCRIPTION OF AQUIFERS AND CONFINING BEDS

The areal geology of the Springfield area is shown on plate 2. This geologic map was prepared by Thomas L. Thompson of the Missouri Division of Geology and Land Survey. A more detailed description of the bedrock geology in the Springfield area is given in section 2, "Areal Geology". Descriptions of the geologic formations and their water-yielding characteristics are summarized in table 4.

In the Springfield area the major (deep) aquifer includes the stratigraphic sequence from the Potosi Dolomite to the Cotter Dolomite (tbl. 4). The Cotter Dolomite is the only part of the aquifer that crops out in the study area (pl. 2).

The major aquifer is over 1,000 feet thick and consists primarily of dolomite with minor sandstone units. Except in the outcrop area, water in the major aquifer is under artesian pressure, being confined between relatively impermeable formations. The concept of one aquifer for this part of the geologic section is based on conformable water levels in wells of varying depths, similar chemical quality of water, similar lithology, and the absence of thick confining shale beds within the section.

The minor (shallow) aquifer is made up of cherty limestones of Mississippian age (tbl. 4). These rocks are present at or near the surface throughout the study area with the exception of the northeastern part of the area and along the upper James River and upper Finley Creek (pl. 2). The rocks making up the minor aquifer are deeply weathered and solution features such as sinkholes and caves are common. Because of the relative openness of the minor aquifer, water has been observed to move through the system as rapidly as 0.3 feet per second (Harvey and Skelton, 1969, C-220). The Northview Formation (tbl. 4), which occurs at or near the base of the minor aquifer, retards the downward movement of water and acts as the upper confining layer to the major aquifer. The thickness of the Northview Formation and the configuration of its base are shown in figures 4 and 5.

The concept of the minor aquifer being distinct from the major aquifer is based on the head differential in water levels in wells finished above and below the Northview Formation. Water levels in wells that tap the minor aquifer are invariably higher than water levels in wells that tap the major aquifer.

The two aquifers can also be distinguished on the basis of chemical quality of water. Water from the minor aquifer is of the calcium bicarbonate type whereas water from the major aquifer is of the calcium-magnesium bicarbonate type.

Table 4

GENERALIZED SECTION OF GEOLOGIC FORMATIONS IN THE SPRINGFIELD AREA*

SYSTEM	SERIES	GROUP	FORMATION	THICKNESS (FT.)	LITHOLOGY	HYDROLOGIC CHARACTERISTICS
QUATERNARY	Pleistocene and Recent		RESIDUUM AND ALLUVIUM	5 - 30	*Residuum* – silt, clay, soil, chert fragments. *Alluvium* – silt, clay, fine grained sand.	Not important as an aquifer in the study area.
PENNSYLVANIAN	Desmoinesian		WARNER FORMATION	0 - 95	Sandstone and conglomerate, very irregular in distribution and thickness.	Not important as an aquifer in the study area.
MISSISSIPPIAN	Meramecian		WARSAW FORMATION	40 - 60	Fine to coarsely crystalline, slightly cherty limestone.	Not important as an aquifer in the study area.
	Osagean		BURLINGTON-KEOKUK LIMESTONE	155 - 270	Medium to coarsely crystalline limestone with nodular and bedded chert.	Minor Aquifer This interval yields small to moderate (1 - 20 gpm) quantities of water to wells in the study area. Springs are common in this horizon. Water draining from this aquifer maintains dry-weather flow of streams. Water is of a calcium-bicarbonate type.
			ELSEY FORMATION	25 - 75	Finely crystalline limestone with abundant nodular and massively bedded chert. In the Springfield area the Elsey Formation rests on the Pierson Formation and is overlain by the Burlington-Keokuk Limestone.	
			REEDS SPRING FORMATION	0 - 125	Gray, grayish-green and red limestone, and green and red calcareous shale. To the south and southwest of the Springfield area the Reeds Spring Formation intervenes between the Pierson and the Elsey.	
			PIERSON FORMATION	5 - 90	*Upper* Cherty limestone and dolomitic limestone. *Lower* Massively bedded brown dolomite.	
	Kinderhookian	Chouteau	NORTHVIEW FORMATION	5 - 80	Brownish siltstone and blue or bluish-green shale.	Confining Layer Upper confining layer for major aquifer. Retards downward movement of water from minor (limestone) aquifer to major (dolomite) aquifer.
			COMPTON FORMATION	2 - 30	Finely crystalline to sublithographic limestone.	Not important as an aquifer in the study area.
			BACHELOR FORMATION	0 - 5	Greenish, quartzose sandstone, with calcareous cement.	
DEVONIAN	Upper		CHATTANOOGA SHALE	0 - 5	Dark gray to black fissile shale.	Thin isolated occurrences recorded in well records. Not hydrologically significant.
			SYLAMORE SANDSTONE	0 - 5	Sandstone with numerous black phosphatic nodules.	
ORDOVICIAN	Canadian		COTTER DOLOMITE	55 - 355	Dolomite, cherty dolomite, bedded chert, and quartz sandstone.	Major Aquifer This sequence acts as a hydrologic unit in this area. Wells open to the total thickness have been pumped at rates of 2,000 gpm. Water from this aquifer is a calcium-magnesium bicarbonate type.
			JEFFERSON CITY DOLOMITE	180 - 250		
			ROUBIDOUX FORMATION	140 - 250		
			UPPER GASCONADE DOLOMITE	40 - 100		
			LOWER GASCONADE DOLOMITE	235 - 320		
			GUNTER SANDSTONE MEMBER	25 - 50		
CAMBRIAN	Upper		EMINENCE DOLOMITE	260 - 350	Dolomite with small amounts of cherty dolomite.	
			POTOSI DOLOMITE	20 - 120		
		Elvins	DERBY - DOERUN DOLOMITE	85 - 105	Dolomite interbedded with thin bedded siltstone and shale.	Confining Layer Probably a confining layer for the overlying dolomite aquifer.
			DAVIS FORMATION	140 - 155	Shale, siltstone, fine-grained sandstone, dolomite and limestone conglomerate.	
			BONNETERRE FORMATION	185 - 260	Medium- to fine-grained, medium bedded dolomite.	Probably not important as an aquifer in the study area.
			LAMOTTE SANDSTONE	180	Quartzose sandstone.	
PRECAMBRIAN					Igneous rocks.	Top of Precambrian is about 2000' below land surface. Does not yield water.

*The stratigraphic nomenclature used in this report is that of the Missouri Division of Geology and Land Survey and differs somewhat from the current usage of the U.S. Geological Survey.

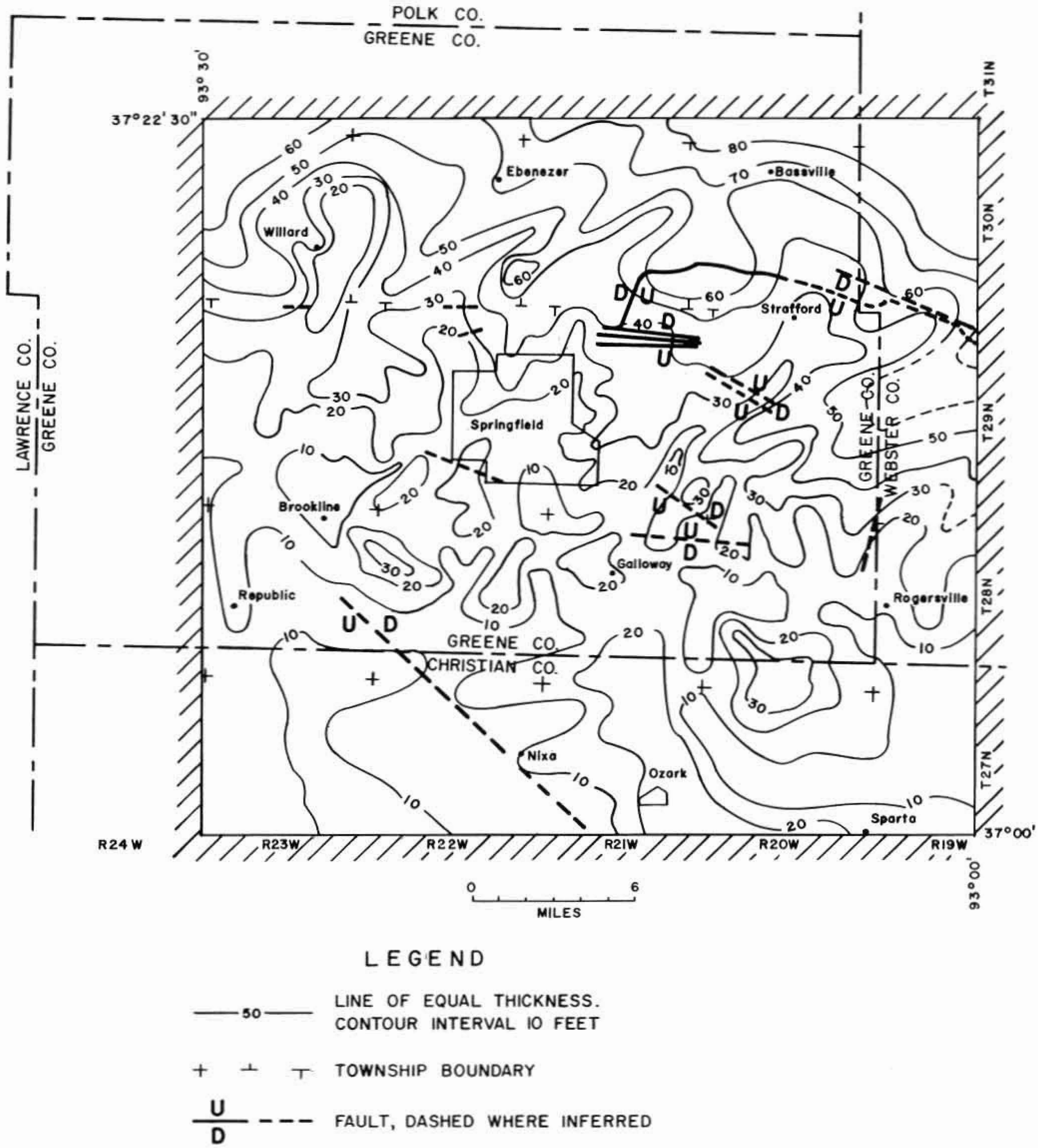


Figure 4

Map showing the thickness of the Northview Formation.

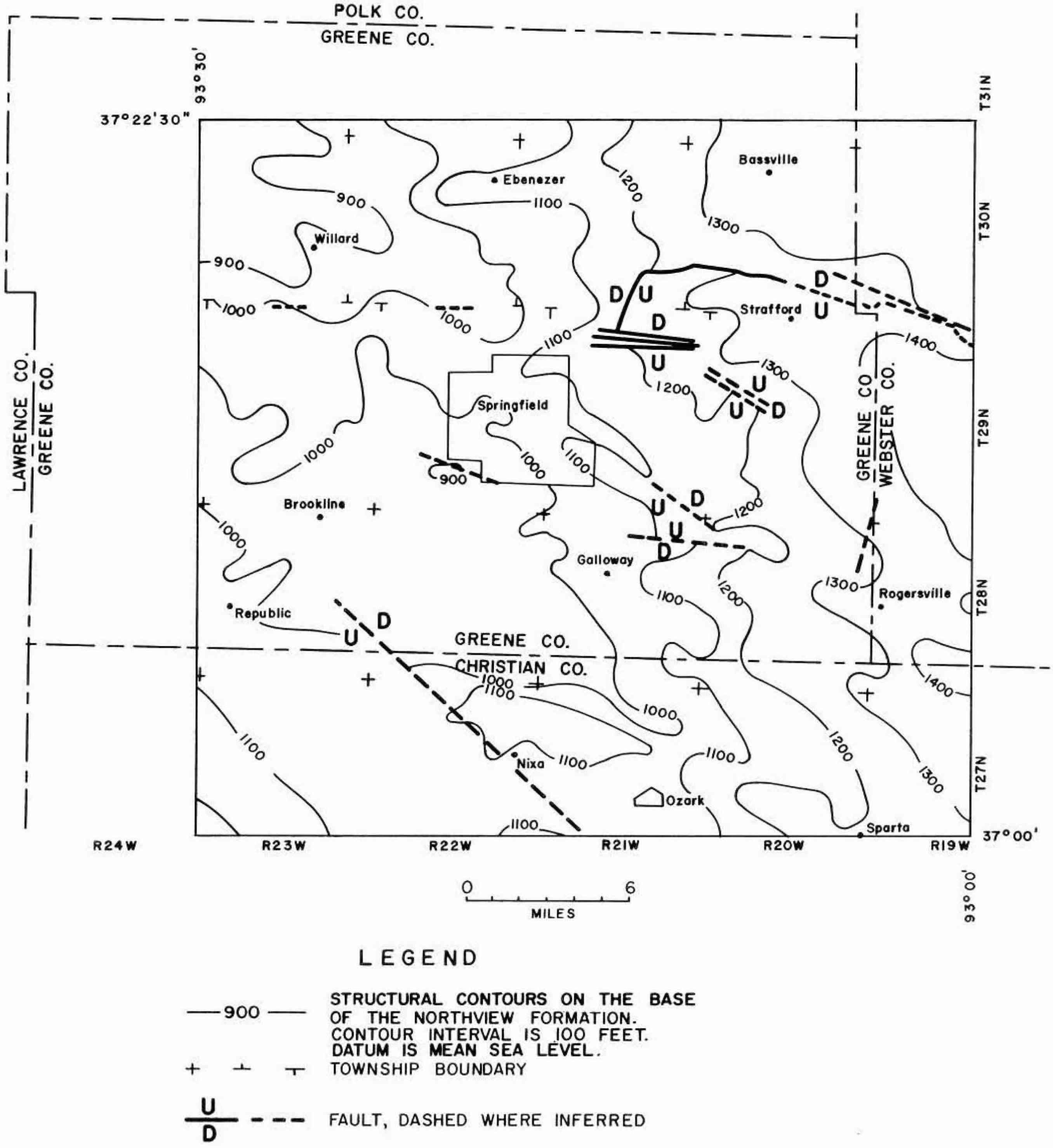


Figure 5

Structure contour map: contoured on the base of the Northview Formation.

RECHARGE TO THE AQUIFERS

Recharge to the aquifers takes place primarily by downward infiltration of precipitation directly in the outcrop and indirectly in the subcrop areas.

The minor aquifer in the Springfield area, which is present at the surface, also is recharged directly from runoff into sinkholes and open joints and through losing reaches of streambeds. In the study area the upper part of the major aquifer is exposed at the surface in only a few areas. Consequently, in most of the study area water recharging the major aquifer must first pass through the minor aquifer and through the Northview Formation before entering the major aquifer. However, the major aquifer also receives recharge outside the study area where the rocks of Cambrian-Ordovician age form the bedrock surface of the Salem Plateau (fig. 3).

Relation of Water Levels in the Aquifers to Precipitation

Water levels in wells that are not appreciably affected by nearby pumping and which are open to the major aquifer reflect seasonal fluctuations in response to precipitation. The hydrograph of the deep well in figure 6 demonstrates this seasonal relationship. It can be seen from the hydrographs that recharge to the major aquifer occurs during the winter and early spring when the moisture requirements for soil and plants are at a minimum. Moisture requirements are greatest during the growing season; consequently, there is little if any recharge to the major aquifer during that period.

Hydrograph records are not available for wells open solely to the minor aquifer. However, the response of the minor aquifer to precipitation can be observed by noting changes in both quantity and turbidity of springflow. As would

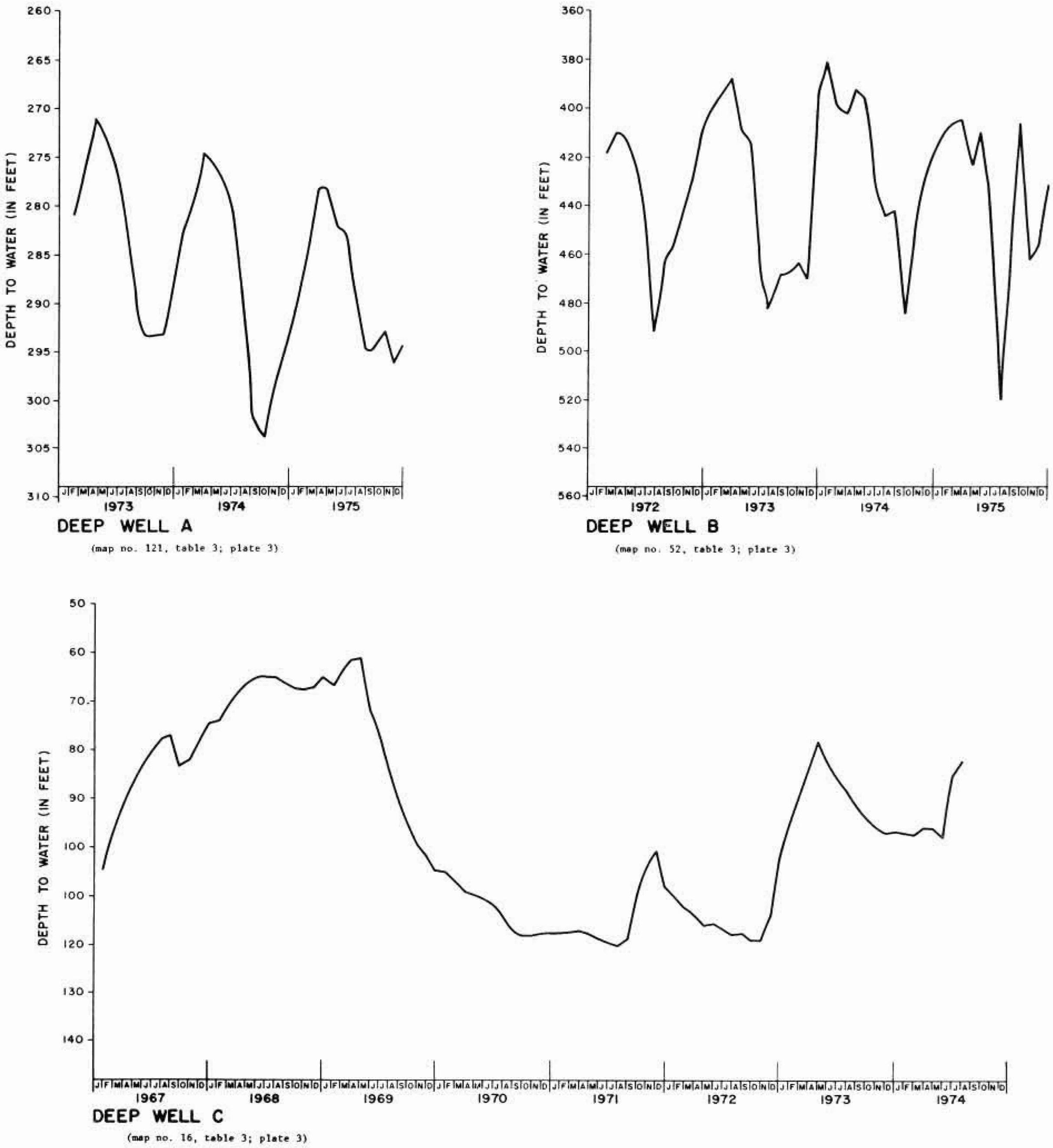


Figure 6

Hydrographs of deep wells.

be expected response to precipitation occurs more rapidly in the minor aquifer than it does in the major aquifer. Seasonal response to precipitation can be seen in the higher base flows which occur in streamflow during the winter and early spring. This is especially evident in the interrupted streams of the area. These streams (such as Pearson, Pickerel, Terrell, South Dry Sac) flow throughout the winter and spring months, but during the rest of the year there are dry reaches on these streams indicating a lowered water level in the aquifer. (See section entitled "Seepage-Run Information".)

Head Relations Between Aquifers

The potentiometric surface of the major aquifer (pl. 3) is below the potentiometric surface of the minor aquifer. This means the potential for vertical movement of ground water is from the minor aquifer to the major aquifer. Inasmuch as recharge is a function of the head differential between the aquifers, increasing the difference between the heads will result in increased recharge to the major aquifer as long as the potentiometric surface in the major aquifer is above the base of the confining bed.

Downward movement is also governed by the vertical permeability and thickness of the Northview Formation. Vertical permeability of the Northview Formation in the Springfield area has been estimated from the aquifer model to be approximately $1x10^{-9}$ feet per second (see p. 109).

Leakage from the overlying shallow aquifer is assumed to be vertical with storage in the confining bed neglected. The flow through the confining layer is described by,

$$q=\frac{K'}{b'}(Hu - h) \quad h>B,$$

$$q=\frac{K'}{b'}(Hu - B) \quad h\leq B,$$

where

q=flux through the confining layer,
K'=vertical permeability of the confining layer,
Hu=head in the minor aquifer,
b'=thickness of the confining layer,
B=base of the confining layer, and
h=head in major aquifer.

It is also assumed that, when the minor aquifer is absent (such as in the northeastern part of the study area), there is no additional recharge due to additional pumping.

Chemical Data As An Indicator of Recharge

Additional evidence that the minor aquifer is a source of recharge to the major aquifer is found in a comparison of the calcium-magnesium ratios of water from the major aquifer in areas where it is overlain by the minor aquifer with ratios in areas where the minor aquifer is missing (fig. 7). In calculating these ratios, concentration values of the calcium and magnesium are expressed in milliequivalents per liter.

Water from the major aquifer (where the minor aquifer is absent) has a calcium-magnesium ratio of about 1.0. As the diagrams for Big Spring and the well at Salem show in figure 7, this ratio is characteristic of water from a dolomite aquifer. At Big Spring the Eminence Dolomite is exposed at the surface. The surface formation at Salem is the Gasconade Dolomite. The well is 850 feet deep and is open to the Potosi Dolomite.

Where the major aquifer is overlain by the minor aquifer (pl. 3, maps no. 2, 3), the water has a calcium-magnesium ratio generally between 1.5 and 2.0 and locally higher. Ratios greater than 1.5 are uncharacteristically high for dolomite and indicate that the major aquifer in the Springfield area is receiving recharge from the minor aquifer.

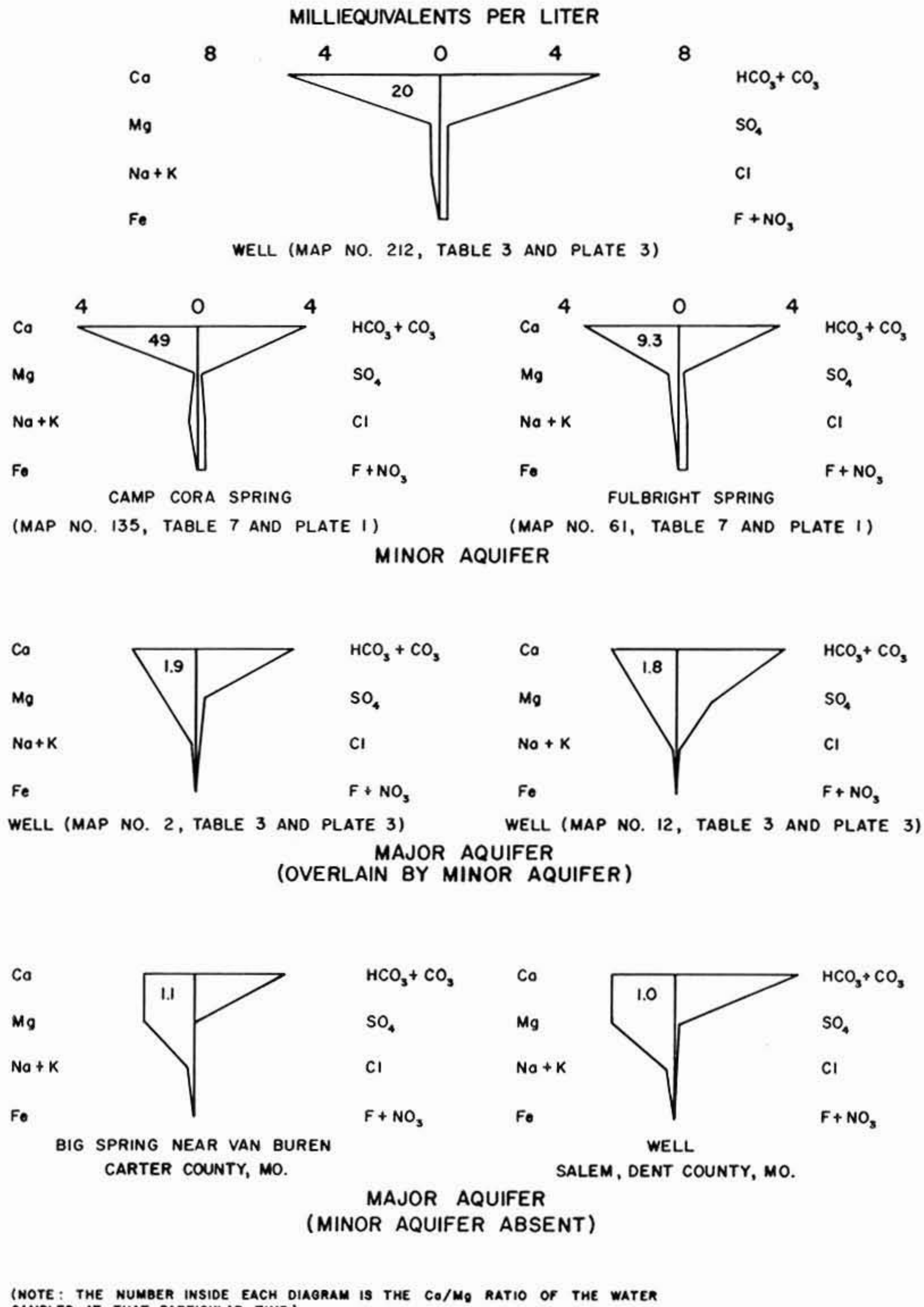


Figure 7

Comparison of chemical analyses of water from the minor and major aquifers.

MOVEMENT OF GROUND WATER

The direction of movement of water in an aquifer can be determined from a potentiometric map. Movement of ground water is in a direction that is down gradient and at right angles to contours depicting the configuration of the potentiometric surface. Plate 3 is a map showing the potentiometric surface of the major aquifer in the Springfield area, Missouri, for June 1974. The most prominent feature of plate 3 is the inverted cone shown by the 850-foot to 1,000-foot potentiometric contours. The lowered potentiometric surface depicted by the inverted cone is the result of groundwater withdrawal from the major aquifer. Groundwater withdrawal has also caused a southward shifting of the groundwater divide.

As can be seen in plate 3, ground water moves into the area from the east and from the southwest toward the pumping centers. North of the groundwater divide and outside of the area of influence due to pumping, the regional movement of ground water is to the northwest. South of the groundwater divide, the regional movement of ground water is toward the south.

There are insufficient data to draw a potentiometric map for the minor aquifer. A generalized groundwater level map of a portion of the area (parts of the Springfield, Brookline, Republic and Nixa $7\frac{1}{2}$-minute topographic maps) was constructed by Williams and Vineyard (Federal Water Pollution Control Administration, 1969, v. 2, App. D). Their map shows that Wilson Creek and the James River act as the major drains for the area south of the topographic divide which passes through Springfield. The map also shows the altitude of the groundwater level in the immediate Springfield area as ranging from 1,150 feet to over 1,225 feet above sea level. This is 100 to 375 feet higher than the altitude of the potentiometric surface of the major aquifer.

DISCHARGE OF GROUND WATER

Withdrawal of ground water from the major aquifer in Springfield has caused a cone of depression which has its deepest part in the central part of the city. The shape of this cone is shown by the potentiometric map in plate 3. The hydrographs in figures 6B and 6C show the effects of pumping from near-

by wells. Figure 6B shows the effects of pumping from a number of closely spaced wells in the deepest part of the cone of depression (pl. 3). As can be seen in figure 6B the seasonal response to precipitation demonstrated in figure 6A is masked by the effects of seasonal pumping. Figure 6C shows the effects of pumping from a well (no. 12, pl. 3) approximately 2 miles away.

Discharge of ground water from the minor aquifer occurs primarily as springs and seepage to local streams. While most water moving through the minor aquifer discharges to nearby streams by way of springs or seepage, some percolates downward into the major aquifer.

With the exception of pumpage from Fulbright Spring by the City of Springfield, withdrawal of water from the minor aquifer is negligible consisting primarily of pumpage for rural domestic use.

AQUIFER CHARACTERISTICS

Information on well yields, drawdown, specific capacity, and length of time the wells were pumped for a particular test is given in table 3. Wells which penetrate the full thickness of the major aquifer generally have the largest specific capacities. This is so not only because a greater thickness is open to the well, but also because the deeper formations are more permeable. In order of decreasing specific capacity they are the Eminence-Potosi, Gunter, Gasconade, and Roubidoux Formations.

Aquifer tests and specific capacity data are not available for wells which tap the minor aquifer. However, it is believed that wells finished in the minor aquifer normally would not yield large amounts of water unless a feeder conduit to one of the larger springs was penetrated. This belief is based on limited well-yield data, and on the fact that water can move rapidly through the upper part of the minor aquifer to points of discharge. In addition, low-flow yields (based on 7-day Q_2) of streams draining the minor aquifer have only one-sixth the yield of streams draining the most permeable part of the major aquifer (Skelton, 1966, p. 20).

Two short-term aquifer tests of 2- and 3-days duration give an apparent transmissivity for the major aquifer of about 4,000 feet ^{2}/d and a storage coefficient of about 10^{-4}. However, the cone of depression formed by pumping (see pl. 3) seems to indicate a much lower re-

gional transmissivity. Consequently, the closed-contour method described by Lohman (1972, p. 46-49) was used to estimate the regional transmissivity. From Lohman's method it was determined that the regional transmissivity is about 670 feet ^{2}/d. This is the value that was used in the aquifer model.

Data in published reports indicate that short-term aquifer tests of carbonate aquifer systems sometimes give anomalously high values for transmissivity. For example, Knowles, Drescher, and LeRoux (1963) ran short-term tests on a dolomite aquifer at the Argonne National Laboratory in Illinois that gave values for transmissivity as much as an order of magnitude higher than the value they obtained by a flow-net type of analysis. Knowles, Drescher, and LeRoux (1963, p. 0 31) explained the high transmissivity obtained from the short-term tests in the following manner:

> "One of the assumptions upon which the nonequilibrium formula is based is that the aquifer is homogeneous and isotropic. Homogeneity and isotropy are relative terms with respect to time and space. For example, after allowing for the distances involved, if the slightly meandering path of water moving toward a well may be described statistically as conforming to the concept of radial flow, the nonequilibrium formula will provide a sound analysis. Conversely, when the flow field is significantly distorted in the area of observation, the assumption of homogeneity is incorrect. At the laboratory, the openings along joints and bedding planes in the Niagara Dolomite are not uniformly disseminated, and in the area sampled by an aquifer test of a few hours or a few days duration, the flow field is probably greatly distorted. Thus, it is concluded that the nonequilibrium formula, or any other method based upon the concept of radial flow, is not applicable to the analysis of data from short-term aquifer tests of the Niagara Dolomite at the Laboratory."

This explanation applies equally as well to the major aquifer in the Springfield area.

Figure 8 illustrates the relationship of aquifer characteristics to drawdown and pumping from the major aquifer. In constructing figure 8 a continuous pumping rate of 1,000 gpm for a 50-year period is assumed. The value for transmissivity was determined by the closed-contour method as previously mentioned. The storage coefficient was determined from aquifer tests and the vertical permeability of the confining layer was obtained from the model study. Thickness of the confining layer is an average for the area. The method used to relate drawdown to pumpage is based on the Hantush-Jacob method as explained in Lohman (1972, p. 30-31).

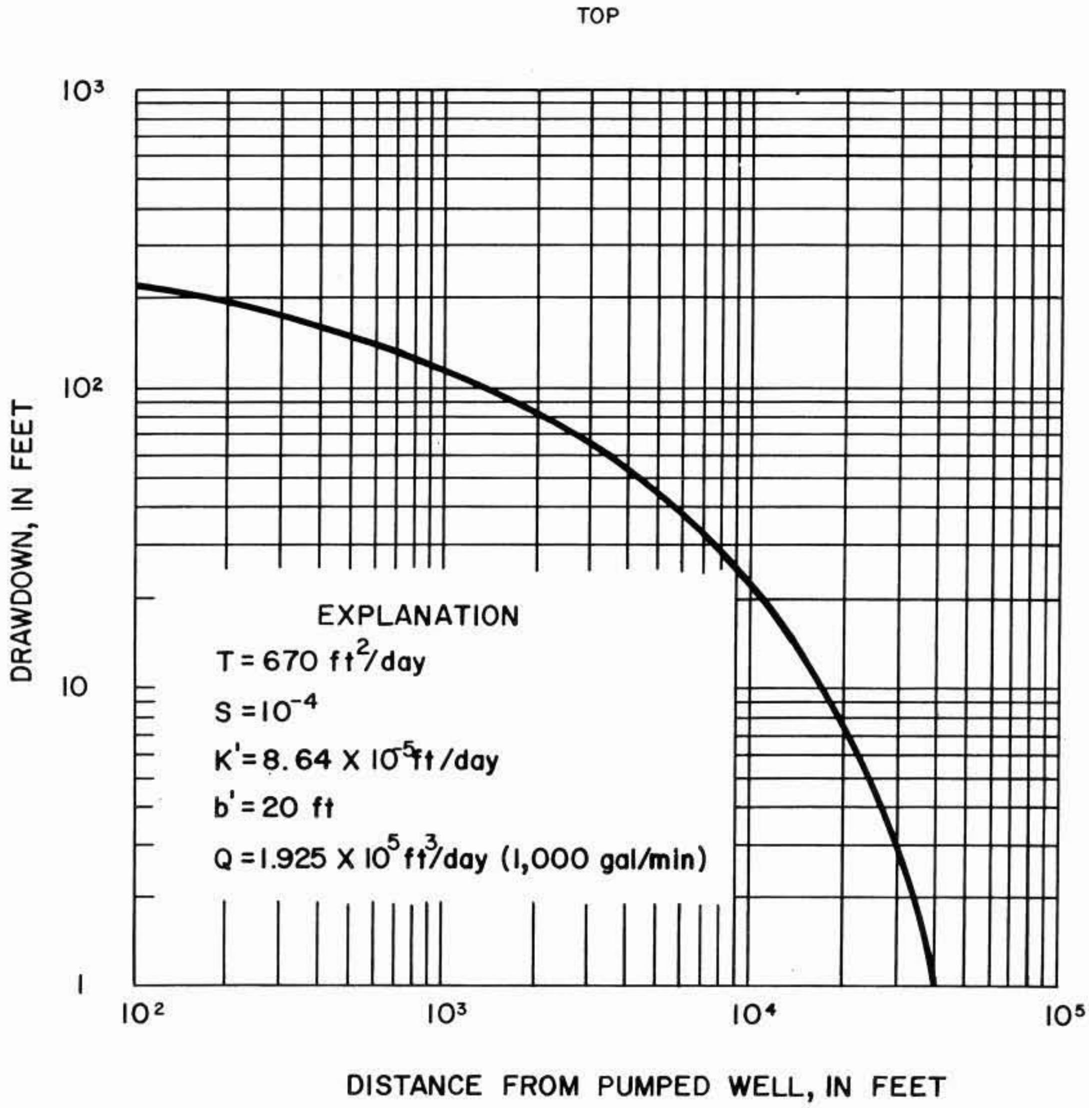


Figure 8

Drawdown at various distances after 50 years of pumping from a well of constant discharge.

QUALITY OF GROUND WATER

Water in the major aquifer differs in chemical composition from water in the minor aquifer in several respects (tbl. 4). Water from wells open to the major aquifer is the calcium-magnesium-bicarbonate type, reflecting the chemical composition of the dolomite which makes up the major aquifer. Water from the minor aquifer is generally of the calcium bicarbonate type reflecting the composition of the limestone which makes up the minor aquifer. Water from the minor aquifer has a higher chloride, nitrate, and total-dissolved solids concentration than water from the major aquifer (fig. 7 and tbl. 5).

Another indication of the chemical character of the water from the minor aquifer is based on analyses of water from springs. Table 6 shows chemical analyses of water from the larger springs in the area. As would be expected (because these springs have their source in the minor aquifer), the analyses are similar to those of water from wells that are open to the minor aquifer (fig. 7).

Although the water in the minor aquifer is chemically distinct from the water in the major aquifer and the two aquifers are separated by a confining layer, water-level measurements in wells indicate a potential for downward movement from the minor to the major aquifer. That there is actual downward leakage through the confining layer is supported by the anomalously high Ca/Mg ratio of water from the major aquifer (tbl. 5). Water from a dolomite aquifer such as the major aquifer in the Springfield area would normally have a Ca/Mg ratio with a value close to 1 (fig. 7).

Water from the minor aquifer generally has a very high Ca/Mg ratio. For example, the Ca/Mg ratio of water from the springs listed in table 6 ranges from about 3 to 40. For the most part, these values reflect the composition of the Burlington-Keokuk Limestones. As shown in table 5 water from wells that tap the limestone of Mississippian age generally have Ca/Mg values greater than 5. Water from those wells displaying values of less than 2 are believed to be in parts of the Mississippian which are mostly chert.

Table 5

QUALITY OF WATER FROM WELLS IN THE SPRINGFIELD AREA

Map number (pl. 3)	Well number	Owner	Depth (ft)	Date of collection	Temperature (°C)	Milligrams per litre: Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Organic nitrogen as N	Ammonia nitrogen as N	Nitrate as N	Dissolved organic carbon	Total phosphorous as P	Dissolved solids (residue at 180°)	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (μ mhos/cm at 25°C)	pH	Colonies per 100 millilitres: Fecal coliform	Colonies per 100 millilitres: Fecal streptococcus	Ca/Mg (ratio in epm)
		Wells that bottom in Potosi Dolomite or older rocks																												
2	28-21-20cdc	Springfield (James River Power Plant)	1,520	2-20-74	16.5	13	0.09	0.00	40	13	1.8	1.1	202	0	10	3.0	0.0	0.15	0.05	0.00	2.2	0.01	190	153	0	348	7.8	<1	<1	1.9
4	28-22-3bcc1	Dayton Rubber Co.	1,640	2-20-74	17.0	13	.09	.01	37	11	1.6	1.0	176	0	12	2.2	.0	.37	.08	.00	.4	.00	174	136	0	315	7.6	<1	<1	2.1
11	29-21-29ddb	General Electric Plant	1,625	2-20-74	17.0	13	.07	.01	30	9.9	1.7	1.0	150	0	12	2.7	.1	.06	.07	.00	.5	.00	165	116	0	277	8.0	<1	<1	1.9
12	29-22-2	Springfield (Fulbright Pump Station CU No. 1)	1,404	4-6-37	--	7.6	.07	--	43	21	(8.8)		224	0	19	4.0	--	--	--	0	--	--	221	--	--	--	--	--	--	--
				2-19-74	16.5	11	.03	.00	43	14	3.3	1.3	214	0	21	4.7	.1	.02	.06	.11	.3	.01	226	167	0	397	7.7	<1	<1	1.8
13	29-22-34bbc1	U.S. Medical Center	1,675	--	16.6	11	.19	.01	33	11	1.2	0.7	172	0	11	1.7	.1	--	--	.0	--	--	166	129	0	300	7.4	--	--	1.8
		Wells that bottom in Eminence Dolomite																												
24	27-22-13cba2	Diversified Plastics	1,282	2-22-74	16.5	16	.09	.01	32	10	1.6	1.0	160	0	9.8	2.0	.2	.15	.04	.00	.0	.01	172	124	0	287	7.9	<1	<1	1.9
25	27-22-13cba3	City of Nixa No. 2	1,284	2-22-74	15.5	14	.12	.00	34	11	1.5	1.0	172	0	9.8	.5	.1	.09	.04	.00	.0	.01	179	131	0	300	7.8	<1	<1	1.9
28	28-21-33cdd	Cassidy Water Co.	1,370	--	16.6	16	.07	.00	48	14	2.1	1.4	224	0	12	1.7	.1	--	--	.0	--	--	209	177	0	430	7.3	--	--	2.1
31	28-22-35ddc	Chalet City South	1,270	--	16.6	16	.72	.00	52	15	2.1	1.3	219	0	13	.7	.1	--	--	.01	--	--	213	180	12	400	7.5	--	--	2.0
33	28-23-20caa	City of Republic No. 2	1,189	--	16.1	17	.24	.01	39	10	1.9	1.2	166	0	6.2	.7	.2	--	--	.0	--	--	164	136	1	300	7.8	--	--	2.3
43	29-22-6cdd	Litton Industries	1,390	2-19-74	17.5	10	0.33	0.01	34	11	1.8	0.8	160	0	14	2.5	0.2	0.06	0.06	0.08	1.3	0.01	170	129	0	295	7.9	<1	<1	1.9
44	29-22-10dcb	Frisco RR	1,275	2-19-74	17.0	12	.13	.01	32	10	1.7	.9	154	0	13	3.2	.1	.04	.06	.01	.0	.01	168	123	0	290	7.9	<1	<1	2.0
50	29-22-14ddc1	Empire Food	1,231	--	16.6	11	.07	.01	38	--	1.4	.9	166	0	12	2.2	.0	--	--	.0	--	--	177	--	--	--	7.2	--	--	--
58	29-22-27cab	Syntex Inc.	1,240	2-20-74	16.5	11	.10	.00	37	10	1.4	.8	184	0	11	1.7	.1	.15	.07	.03	.1	.01	173	135	0	304	7.8	<1	<1	2.2
		Wells that bottom in Gunter Sandstone Member, Gasconade Dolomite																												
62	28-22-7aaa1	Springfield (SW Sewage Treatment Plant)	1,080	2-20-74	16.5	12	.20	.01	36	11	2.0	1.1	180	0	11	2.2	.0	.01	.08	.00	.5	.01	179	134	0	311	7.8	<1	<1	2.0
63	28-22-20cab1	Greene County PWSD No. 1 (Battlefield)	1,225	--	16.6	14	.16	.01	43	13	2.6	2.0	185	0	13	1.5	.4	--	--	.0	--	--	185	152	9	330	7.7	--	--	2.0
		Wells that bottom in Gasconade Dolomite																												
73	28-19-19aca	City of Rogersville	1,260	2-21-74	14.0	14	.09	.01	50	10	3.0	1.1	224	0	9.0	7.0	.1	.15	.03	2.0	1.2	.01	244	166	0	395	7.4	<1	<1	3.0
77	28-23-20cbb1	City of Republic No. 1	1,000	3- -74	16.1	14	.05	.01	39	12	2.1	1.3	179	0	7.6	2.5	.2	--	--	.0	--	--	176	144	0	280	7.7	--	--	2.0
86	30-20-17acb	Acres of Shade Trailer Park	729	2-19-74	15.5	13	.23	.01	52	18	3.3	1.8	276	0	36	3.2	.1	.10	.07	.02	1.1	.01	277	205	0	498	7.6	<1	<1	1.8
		Wells that bottom in the Roubidoux Formation																												
88	28-20-8aad1	Logan Elementary School R8	758	--	16.6	14	.56	.01	39	12	1.9	1.2	179	3.6	13	2.0	0.1	--	--	.0	--	--	186	147	0	320	7.8	--	--	1.8
89	28-20-13bcd	Logan-Rogersville High School	685	2-21-74	14.0	12	.09	.00	42	14	1.9	1.4	214	0	17	2.7	.1	.02	.05	.01	.0	.01	221	160	0	376	7.7	<1	<1	1.9
93	28-21-4ccc	Valley Park Subdivision	685	2-22-74	10.0	12	.20	.01	34	10	2.3	1.7	162	0	13	2.7	.3	.14	.08	.02	--	.01	181	126	0	296	7.9	<1	<1	2.0
95	28-21-9bdb	Sequiota Park	630	2-21-74	15.0	10	.12	.01	28	9.7	6.1	3.1	156	0	12	2.7	.7	.05	.17	.01	--	.01	164	111	0	297	7.8	<1	<1	1.8
116	29-21-34dcd1	Ridgeview Terrace Subdivision	800	2-21-74	15.0	8.8	.12	.00	32	10	2.4	2.1	154	0	15	3.2	.4	.05	.09	.02	1.6	.01	161	124	0	303	7.9	<1	<1	1.9
		Wells that bottom in Jefferson City Dolomite																												
137	28-21-21bdd	J. Sacks	600	6-25-75	20.0	--	--	--	31	14	--	--	184	0	--	2.4	--	.00	.04	.00	--	.01	--	140	0	290	7.5	--	--	1.3
138	28-21-21dbb	H. Cassey	505	6-25-75	16.0	--	--	--	33	12	--	--	166	0	--	4.5	--	.04	.04	.02	--	.01	--	130	0	282	7.4	--	--	1.7
141	28-23-1abb	Datema Wood Products	510	5-20-75	17.0	--	--	--	42	18	--	--	200	0	--	1.9	--	.14	.00	.42	--	.00	--	180	15	282	7.5	--	--	1.4
142	28-23-1bdd	Whispering Lanes Trailer Park	450	3-6-74	16.5	11	.10	.01	38	9.9	4.9	2.6	186	0	12	.7	.5	.11	.02	.44	.6	.00	178	134	0	340	7.8	<1	<1	2.3
				5-20-75	16.0	--	--	--	34	16	--	--	200	0	--	1.8	--	.1	.00	.33	--	.00	--	150	0	280	7.7	--	--	1.3

Table 5 (continued).....

Map number (pl. 3)	Well number	Owner	Depth (ft)	Date of collection	Temperature (°C)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Organic nitrogen as N	Ammonia nitrogen as N	Nitrate as N	Dissolved organic carbon	Total phosphorous as P	Dissolved solids (residue at 180°)	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (µmhos/cm at 25°C)	pH	Colonies per 100 millilitres: Fecal coliform	Colonies per 100 millilitres: Fecal streptococcus	Ca/Mg (ratio in epm)
						Milligrams per litre																								
												Wells that bottom in Jefferson City Dolomite--Continued																		
143	28-23-10acd	Mr. Todhunter	450	5-20-75	16.0	--	--	--	52	24	--	--	272	0	--	4.8	--	.08	.00	.55	--	.00	--	230	6	365	7.4	--	--	1.3
145	28-23-17ada	John Sparkman	528	5-20-75	16.5	--	--	--	37	17	--	--	192	0	--	2.2	--	.05	.01	.26	--	.00	--	160	5	273	7.5	--	--	1.3
146	28-23-23cba	U.S. National Park Service	550	1-16-68	--	7.0	--	--	41	18	2.5	3.3	206	0	17	1.2	.4	--	--	.04	--	.00	186	176	7	350	7.8	--	--	1.4
147	28-23-25bdd	U.S. National Park Service	525	10-18-73	15.0	9.3	0.20	0.01	34	12	3.7	2.7	171	0	12	3.2	1.1	--	--	.0	--	--	132	134	0	--	--	--	--	1.8
155	29-21-10aaa	Bells Motor Court	395	2-21-74	15.5	13	.09	.00	36	12	2.6	1.9	184	0	26	1.7	.5	.05	.09	.00	1.0	.00	200	138	0	350	7.8	<1	<1	1.8
156	29-22-18dcd	Seven Gables Truck Stop	640	3-7-74	16.5	10	.11	.01	40	11	1.9	1.9	182	0	14	.7	.3	.08	.12	.04	.3	.00	170	145	0	320	7.6	<1	<1	2.3
159	29-2½-15baa	M. Batson	455	6-25-75	16.0	--	--	--	35	19	--	--	228	0	--	1.8	--	.09	.03	.03	--	.01	--	170	0	360	7.5	--	--	1.1
164	30-21-1bbb	R. D. Ryan	305	5-20-75	16.0	--	--	--	110	61	--	--	480	0	--	11	--	.12	.00	.76	--	.00	--	530	130	850	7.3	--	--	1.1
165	30-21-2acb	Mr. Little	320	5-20-75	16.0	--	--	--	120	8.8	--	--	340	0	--	69	--	.18	.00	2.0	--	.00	--	340	57	750	6.9	--	--	8.3
166	30-21-2bda	H. Crane	395	5-20-75	15.5	--	--	--	110	35	--	--	304	0	--	18	--	.10	.01	.09	--	.01	--	420	170	510	7.4	--	--	1.9
168	30-21-3ddd	Mr. Andrus	500	5-20-75	17.0	--	--	--	73	16	--	--	260	0	--	9.0	--	.18	.00	.01	--	.00	--	250	35	440	7.5	--	--	2.8
170	31-21-35cbc	Peace Chapel	300	5-20-75	17.0	--	--	--	130	120	--	--	532	0	--	240	--	.17	.00	.43	--	.00	--	820	380	1800	6.8	--	--	.7
171	31-21-36cca	J. Delashmit	457	5-20-75	15.0	--	--	--	110	65	--	--	548	0	--	7.6	--	.09	.00	.04	--	.00	--	540	93	820	7.0	--	--	1.0
												Wells that bottom in Cotter Dolomite																		
176	27-21-3bba	J. Taylor	424	3-4-74	14.5	12	0.18	0.01	40	9.8	2.8	2.0	182	0	13	.7	.3	.18	.05	.08	1.0	.00	167	139	0	330	7.8	<1	1	1.9
185	28-21-20ddb	Mr. Ambler	210	6-25-75	17.0	--	--	--	38	18	--	--	274	0	--	7.2	--	.03	.24	.00	--	.01	--	170	0	460	7.4	--	--	1.3
186	28-21-21ccd	Mr. Day	400	6-25-75	17.0	--	--	--	75	25	--	--	334	0	--	7.8	--	.06	.02	.38	--	.01	--	290	16	600	7.2	--	--	1.8
187	28-21-28aab	Mr. Larimore	430	6-25-75	16.0	--	--	--	21	.6	--	--	208	0	--	2.6	--	.03	.02	.03	--	.01	--	55	0	360	7.6	--	--	--
188	28-21-28adb	Mr. L. Plank	375	6-25-75	16.0	--	--	--	32	14	--	--	204	0	--	4.4	--	.03	.01	.28	--	.01	--	140	0	375	7.5	--	--	1.4
192	28-23-1cbb	H. Simpson	426	3-6-74	14.5	9.5	.30	.01	41	14	2.5	.9	224	0	2.5	1.2	.0	.06	.04	.37	3.0	.00	194	158	0	520	7.7	<1	<1	1.8
193	28-23-1cbc	Ozark Structures	420	5-20-75	19.0	--	--	--	36	19	--	--	208	0	--	2.0	--	.18	.00	.16	--	.00	--	170	0	305	7.5	--	--	1.1
195	28-23-10cca	Mr. Eckles	424	5-20-75	16.0	--	--	--	97	6.3	--	--	332	0	--	5.0	--	.14	.00	1.1	--	.00	--	270	0	440	7.2	--	--	9.3
196	28-23-11ccc	Thomas	350	5-20-75	15.0	--	--	--	80	2.1	--	--	236	0	--	6.4	--	.11	.00	4.3	--	.00	--	210	15	340	7.2	--	--	23
197	28-23-14bbd	Ghys	425	5-20-75	17.0	--	--	--	71	2.6	--	--	228	0	--	4.0	--	.12	.00	3.1	--	.00	--	190	1	325	7.3	--	--	17
199	28-23-21abb	Logan	320	5-20-75	17.0	--	--	--	41	22	--	--	220	0	--	2.5	--	.10	.00	.08	--	.00	--	190	13	312	7.6	--	--	1.1
206	29-22-29cdd	Chula Vista Trailer Park	500	3-7-74	15.0	10	0.03	0.01	44	12	1.7	1.7	224	0	16	2.2	1.0	.02	.08	.07	.3	.00	193	158	6	350	7.8	<1	<1	2.2
207	29-23-9cdc	Haney	360	6-25-75	16.0	--	--	--	56	27	--	--	288	0	--	3.9	--	.03	.01	.07	--	.01	--	250	15	465	7.3	--	--	1.3
208	29-23-16bbc	Anderson	437	6-25-75	19.0	--	--	--	81	1.9	--	--	292	0	--	5.1	--	.05	.31	.63	--	.02	--	210	0	435	7.0	--	--	26
209	29-23-18acc	R. Silverthorn	210	3-7-74	15.5	9.5	.05	.01	48	17	2.3	1.6	266	0	12	1.7	.2	.07	.08	.18	.4	.04	234	190	0	420	7.7	--	--	1.8
211	30-21-3ada	McWilliams	150	5-20-75	16.0	--	--	--	120	8.4	--	--	324	0	--	100	--	.30	.00	23	--	.03	--	330	69	710	7.2	--	--	8.7
												Wells that bottom in Limestone of Mississippian age																		
212	27-22-2aaa	F. E. Weddington	175	3-4-74	14.5	17	.14	.01	102	3.2	4.0	1.7	322	0	12	8.7	.0	.04	.05	3.0	1.9	.01	332	268	17	570	7.3	<1	2	20
213	27-23-5bac	R. Sims	88	3-5-74	14.5	11	.11	.01	46	17	17	2.8	256	0	24	18	1.0	.01	.09	.50	.4	.00	276	185	0	500	7.7	<1	<1	1.7
214	27-23-18dbd	L. Little	215	3-7-74	13.5	10	.15	.01	52	19	2.4	1.1	296	0	10	4.2	.0	.00	.07	.09	.7	.00	245	208	0	460	7.6	<1	<1	1.6
215	28-22-6bcb	Henry	90	5-20-75	17.0	--	--	--	71	1.8	--	--	216	0	--	4.0	--	.07	.00	2.7	--	.01	--	180	8	330	7.4	--	--	24
216	28-22-20cbc	J. Hampton	290	3-5-74	12.0	9.4	.04	.01	69	15	4.9	1.3	286	0	18	13	.1	.05	.01	.05	2.5	.00	234	235	72	540	7.5	<1	<1	2.7

Table 5 (continued).....

Map number (pl. 3)	Well number	Owner	Depth (ft)	Date of collection	Temperature (°C)	Milligrams per litre: Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Organic nitrogen as N	Ammonia nitrogen as N	Nitrate as N	Dissolved organic carbon	Total phosphorous as P	Dissolved solids (residue at 180°)	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (micromhos at 25°C)	pH	Colonies per 100 millilitres: Fecal coliform	Colonies per 100 millilitres: Fecal streptococcus	Ca/Mg (ratio in epm)
						Wells that bottom in Limestone of Mississippian Age--Continued																								
217	28-23-3dad	Potter	32	5-20-75	16.0	--	--	--	82	8.6	--	--	136	0	--	31	--	.01	.00	26	--	.00	--	240	130	547	7.0	--	--	5.8
218	28-23-27aaa	B. McConnell	266	3-5-74	14.5	13	0.22	0.01	124	4.0	10	8.7	312	0	26	24	.0	.00	.09	20	3.5	.00	471	326	90	750	7.0	<1	<1	19
220	29-23-9ddd1	Mark	110	6-25-75	18.5	--	--	--	120	3.5	--	--	384	0	--	28	--	.15	.03	3.8	--	.03	--	310	0	740	7.0	--	--	21
221	29-23-9ddd2	Gibson	150	6-25-75	20.0	--	--	--	96	.8	--	--	308	0	--	13	--	.03	.02	1.6	--	.01	--	240	0	540	7.0	--	--	73
222	29-29-15acb	Howell	125	5-21-75	15.0	--	--	--	120	3.6	--	--	--	--	--	12	--	.13	.00	6.4	--	.00	--	310	--	480	--	--	--	20
223	30-23-24aba	R. G. Shelton	149	3-6-74	15.0	13	.08	.01	55	14	9.5	.9	278	0	3.8	4.7	.0	--	--	--	--	--	257	193	0	470	7.5	--	--	2.5
224	31-23-33ddb	R. Forshee	180	3-6-74	14.5	14	.27	.01	64	23	2.8	1.3	336	0	26	6.7	.1	.18	.09	.15	.4	.00	335	254	0	570	7.4	<1	<1	1.7

QUALITY OF WATER FROM SELECTED SPRINGS IN THE SPRINGFIELD AREA

Analyses by U.S. Geological Survey and Missouri Division of Geology and Land Survey

(values centered in sodium-potassium columns are sodium plus potassium calculated as sodium)

Map number (pl. 1)	Spring	Date of collection	Discharge (ft³/s)	Temperature (°C)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Organic nitrogen as N	Ammonia nitrogen as N	Nitrate as N	Dissolved organic carbon	Total phosphorous as P	Dissolved solids (residue at 180°)	Hardness as $CaCO_3$		Specific conductance (µ mhos/cm at 25°C)	pH (units)	Dissolved oxygen		Colonies per 100 millilitres		
																							Calcium magnesium	Noncarbonate			Milligrams per liter	Percent saturation	Total coliform	Fecal coliform	Fecal streptococci
Sac River basin																															
40	Brower	2-74	---	15.5	15.5	0.13	0.01	60	4.9	3.6	1.1	184	0	3.1	11	0.1	---	---	3.7	---	---	211	152	17	---	7.8	---	---	---	---	---
		3-74	2.76	14.0	---	---	---	62	4.7	---	---	204	0	---	---	---	.08	.07	3.4	.7	.01	---	174	7	420	7.3	---	---	---	7	9
		8-74	.60	15.0	---	---	---	77	5.7	---	---	---	---	---	16	---	.15	.01	3.6	---	.03	---	---	---	440	7.4	8.8	86	---	---	---
75	Cave	8-25	---	---	8.0	.23	---	91	0.8	(3.8)		273	0	6.4	4.9	---	---	---	1.9	---	---	258	---	---	---	---	---	---	---	---	---
		5-55	---	14.4	5.8	.03	.00	85	8.9	(4.8)		256	0	8.6	5.0	.1	---	---	7.5	---	---	286	210	38	---	7.2	---	---	---	---	---
		8-64	.12	14.4	11	.00	.00	89	9.7	3.0	1.1	284	0	9.8	4.7	.1	---	---	4.5	---	.00	288	262	30	508	7.9	---	---	---	---	---
		10-72	1.08	14.0	12	.14	.01	94	5.3	3.1	1.3	280	0	11	7.7	.1	---	---	3.3	---	---	309	226	32	510	7.1	6.6	63	240	45	90
		6-73	.14	14.0	---	---	---	---	---	---	---	260	0	---	---	---	---	---	---	---	---	---	---	---	478	7.0	5.4	52	---	8	32
		10-73	.56	14.5	---	---	---	---	---	---	---	282	0	---	---	---	---	---	---	---	---	---	---	---	475	7.1	5.5	53	---	8	6
		3-74	1.36	13.5	11	.13	.01	79	4.0	2.4	1.3	256	0	11	6.7	.1	.04	.07	2.2	1.0	.01	278	204	10	460	7.2	---	---	---	4	2
		8-74	.30	14.0	---	---	---	87	8.1	---	---	---	---	---	7.8	---	.17	.02	2.7	---	.02	---	---	---	490	7.1	6.2	60	---	---	---
38	Clear Creek	9-64	1.84	15.0	12	.03	.00	85	2.4	5.5	.6	244	0	8.4	9.6	.0	---	---	3.2	---	.01	269	222	22	451	8.0	---	---	---	---	---
		5-72	1.46	16.0	13	.15	.02	86	2.0	3.2	.7	248	0	7.8	6.2	.0	---	---	2.4	---	---	255	193	31	400	7.2	5.4	55	92	5	110
		10-72	2.44	14.5	13	0.21	0.02	78	1.7	4.0	0.9	240	0	3.7	7.2	0.1	---	---	3.4	---	---	268	195	6.3	435	7.2	7.1	69	360	10	70
		6-73	1.70	16.5	---	---	---	---	---	---	---	228	0	---	---	---	---	---	---	---	---	---	---	---	400	7.0	4.2	43	---	8	120
		10-73	.76	15.0	---	---	---	---	---	---	---	252	0	---	---	---	---	---	---	---	---	---	---	---	430	7.1	5.7	56	---	420	340
61	Fulbright	8-25	---	---	8.8	1.6	---	72	1.7	(0.9)		229	0	3.3	6.1	---	---	---	1.1	---	---	210	---	---	---	---	---	---	---	---	---
		4-37	---	---	5.6	.06	.01	65	2.6	(6.6)		188	0	4.7	4.4	.1	---	---	3.1	---	---	224	---	---	---	---	---	---	---	---	---
		4-71	---	---	8.0	.11	.01	62	4.0	3.6	1.1	207	0	8.0	13	.0	---	---	---	---	---	238	170	1.8	---	---	---	---	---	---	---
		5-72	12.0	14.5	9.8	.19	.01	76	3.6	4.2	.9	224	0	9.6	11	.0	---	---	2.3	---	---	251	177	28	390	7.4	7.0	68	220	28	200
		10-72	---	15.0	13	0.31	0.03	80	3.4	4.5	1.2	244	0	8.5	10	0.1	---	---	3.7	---	---	250	187	26	420	7.6	6.4	63	140	28	130
		2-73	---	11.5	12	.39	.04	62	4.3	4.2	1.2	210	0	7.3	10	.0	---	---	3.3	---	---	235	173	.5	400	7.4	---	---	---	---	---
		10-73	5.9	15.0	---	---	---	---	---	---	---	232	0	---	---	---	---	---	---	---	---	---	---	---	430	7.1	6.2	61	---	300	110
		2-74	---	12.2	12	.22	.02	63	4.1	3.6	1.1	206	0	7.5	11	.0	---	---	2.6	---	---	227	169	4.5	---	7.4	---	---	---	---	---
		3-74	18.9	12.0	---	---	---	69	2.7	---	---	212	0	---	---	---	0.26	0.01	2.9	0.8	0.00	---	183	9	390	7.4	---	---	---	17	7
50	J. Hart	9-64	1.94	15.0	11	.04	0.00	79	2.8	2.5	0.5	233	0	2.8	4.5	0.0	---	---	4.5	---	0.01	241	209	18	412	7.8	---	---	---	---	---
		5-72	.67	15.0	13	.15	.01	83	2.7	1.6	.6	244	0	3.6	6.7	.0	---	---	.1	---	---	247	200	18	395	7.2	7.6	75	160	25	70
		10-72	4.94	14.5	10	.14	.01	74	1.7	2.4	.8	236	0	3.1	5.0	.1	---	---	3.3	---	---	235	191	1.3	420	7.2	7.2	70	200	5	80
		6-73	6.7	14.5	---	---	---	---	---	---	---	236	0	---	---	---	---	---	---	---	---	---	---	---	405	7.1	7.7	75	---	6	8
		10-73	2.4	14.5	---	---	---	---	---	---	---	236	0	---	---	---	---	---	---	---	---	---	---	---	415	7.2	7.5	73	---	14	10
1	Hayes	9-64	1.52	15.0	9.2	.00	.00	73	3.4	2.9	.7	211	0	6.0	5.0	.0	---	---	4.5	---	.01	228	196	22	397	7.6	---	---	---	---	---
		5-72	2.24	15.0	12	.10	.01	84	2.9	2.0	.9	236	0	8.8	7.2	.0	---	---	3.1	---	---	257	184	37	395	7.4	7.4	73	960	230	230
		10-72	3.65	14.0	12	.42	.02	76	1.8	3.0	1.2	212	0	4.3	8.7	.0	---	---	4.9	---	---	248	173	25	422	7.1	7.0	67	1700	1200	1400
		6-73	4.6	14.5	---	---	---	---	---	---	---	200	0	---	---	---	---	---	---	---	---	---	---	---	375	7.1	6.4	62	---	6	28
		10-73	1.6	14.5	---	---	---	---	---	---	---	220	0	---	---	---	---	---	---	---	---	---	---	---	405	7.1	6.0	58	---	38	62
2	Silverthorn	2-74	---	12.2	15	.27	.02	69	1.3	4.0	1.0	222	0	5.5	8.7	.1	---	---	4.1	---	---	237	178	0	---	7.5	---	---	---	---	---
		3-74	2.14	13.0	14	.18	.01	71	1.8	4.0	1.2	228	0	4.3	7.7	.0	.13	.05	3.3	.6	.00	226	182	3.2	420	7.4	---	---	---	62	44

Note: Temperature, specific conductance, and dissolved oxygen are field determinations.
Bicarbonate, carbonate and pH are also field determinations from 1972 to present.

Table 6 (continued).....

Map number (pl. 3)	Spring	Date of collection	Discharge (ft³/s)	Temperature (°C)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Organic nitrogen as N	Ammonia nitrogen as N	Nitrate as N	Dissolved organic carbon	Total phosphorous as P	Dissolved solids (residue at 180°)	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (µmho/cm at 25°C)	pH (units)	Dissolved oxygen: Milligrams per liter	Dissolved oxygen: Percent saturation	Colonies per 100 milliliters: Total coliform	Colonies per 100 milliliters: Fecal coliform	Colonies per 100 milliliters: Fecal streptococci
														Sac River basin--continued																	
64	Williams	10-64	1.13	14.4	9.4	.00	0.00	74	3.5	16	1.0	190	0	34	24	0.2	---	---	2.2	---	0.00	270	199	44	478	8.1	---	--	---	---	---
		5-72	2.89	14.0	10	.19	.06	83	3.5	6.1	1.5	232	0	28	12	.4	---	---	3.2	---	---	276	182	39	450	7.2	8.0	77	30	2	8
		10-72	13.8	14.0	13	.17	.05	76	3.3	6.2	2.0	220	0	17	13	.3	---	---	4.1	---	---	276	175	29	450	7.1	4.6	44	50	9	34
		6-73	4.4	14.5	---	---	---	--	---	---	---	204	0	---	---	---	---	---	---	---	---	---	---	--	442	6.8	3.5	34	---	2	24
		10-73	1.56	14.5	---	---	---	--	---	---	---	224	0	---	---	---	---	---	---	---	---	---	---	---	575	6.9	7.3	71	---	10	4
		3-74	6.22	14.0	13	.07	.02	75	2.8	4.9	2.0	220	0	16	14	.7	.20	3.1	4.2	.9	.04	309	157	42	480	7.0	---	--	---	2	4
														White River basin																	
143	Blue	8-64	2.3	14.4	12	.00	---	84	1.9	3.3	.8	244	0	2.4	4.9	.01	---	---	3.8	---	.00	257	218	18	428	7.8	---	--	---	---	---
		3-74	8.44	14.0	14	.13	0.01	78	1.2	3.0	1.1	218	0	3.0	8.2	.0	0.13	0.09	3.9	2.0	.01	240	175	26	420	7.1	---	---	---	2	4
		8-74	4.5	14.0	---	---	---	81	1.5	---	---	---	--	---	7.5	---	.03	.02	3.8	---	.04	---	---	---	440	7.0	9.0	86	---	---	---
135	Camp Cora	5-72	5.77	14.0	13	.28	.01	77	1.1	3.4	1.0	204	0	5.4	9.7	.0	---	---	2.6	---	---	248	176	20	380	7.4	8.9	86	88	17	78
		10-72	20.4	14.0	13	.25	.02	81	1.2	4.7	1.6	232	0	5.4	9.2	.1	---	---	4.1	---	---	271	189	17	422	7.4	7.6	73	1200	66	150
		6-73	4.6	15.5	---	---	---	--	---	---	---	242	0	---	---	---	---	---	---	---	---	---	---	---	438	7.1	8.3	83	---	20	34
		10-73	2.31	15.0	---	---	---	--	---	---	---	260	0	---	---	---	---	---	---	---	---	---	---	---	458	7.3	8.8	87	---	74	720
		3-74	8.72	12.0	16	.08	.01	80	1.0	4.0	1.3	230	0	3.8	8.7	.0	.05	.03	2.9	1.0	.01	232	167	37	420	7.7	---	--	---	40	28
		8-74	3.0	16.0	---	---	---	85	1.8	---	---	---	--	---	12	---	.02	.02	2.9	---	.07	---	---	---	440	7.2	8.9	89	---	---	---
165	Double	3-74	12.9	11.5	13	.13	.01	80	1.2	3.0	1.3	224	0	3.8	6.7	.1	.15	.07	3.3	1.0	.01	252	205	31	400	7.6	---	--	---	20	4
125	Jones	8-25	1.23	---	9.6	1.0	---	86	3.5	(15)		262	0	10	15	---	---	---	2.3	---	---	269	228	29	---	---	---	--	---	---	---
		11-52	---	13.9	7.4	.04	.00	91	3.5	(16)		240	0	---	21	3.2	---	---	4.7	---	---	312	243	45	---	7.7	---	--	---	---	---
		8-64	1.60	14.4	12	.01	.2	98	3.0	8.9	2.8	218	0	37	18	4.3	---	---	6.8	---	---	336	257	78	550	7.2	---	--	---	---	---
		5-72	3.28	14.0	14	.26	.06	90	2.3	6.1	1.4	280	0	22	17	.2	---	---	5.3	---	---	360	224	11	520	6.9	6.2	60	750	52	2000
		10-72	1.98	14.0	12	.21	.03	99	1.8	7.8	1.4	292	0	13	13	.1	---	---	4.5	---	---	321	233	21	530	7.1	7.2	69	700	24	72
		6-73	1.8	14.5	---	---	---	--	---	---	---	278	0	---	---	---	---	---	---	---	---	---	---	---	545	6.8	7.0	68	---	11	10
		10-73	1.37	14.0	---	---	---	--	---	---	---	294	0	---	---	---	---	---	---	---	---	---	---	---	580	6.8	7.0	67	---	16	16
		3-74	2.11	14.0	13	.06	.01	88	2.3	6.4	1.7	274	0	14	14	.1	.00	.14	5.0	4.4	.02	342	219	9.5	520	7.1	---	--	---	28	2
194	Patterson	3-74	9.22	13.5	14	.08	.00	49	6.2	2.9	1.2	168	0	6.6	7.7	.1	.08	.01	1.6	.8	.00	183	134	13	305	7.5	---	--	---	16	2
		8-74	11	14.0	---	---	---	49	10	---	---	---	--	---	7.3	---	---	.03	1.3	---	.02	---	---	---	360	7.3	9.0	86	---	---	---
168	Porter	3-74	8.24	12.0	13	0.34	0.05	78	2.5	4.0	1.5	228	0	5.7	8.7	0.1	.22	0.03	3.1	0.7	0.12	246	178	26	430	7.3	---	---	---	82	10
149	Rader	10-64	15.3	17.8	12	.24	.00	58	9.7	63	9.8	140	0	32	66	.6	---	---	18	---	5.2	422	185	70	710	7.3	---	--	---	---	---
		9-70	35.2	16.5	11	.44	.08	80	4.0	3.3	2.8	258	0	16	26	.2	---	---	5.4	---	---	336	199	18	555	7.0	---	--	---	---	---
		2-73	---	11.1	9.0	.72	.11	87	3.6	7.7	1.7	225	0	13	17	.0	---	---	4.6	---	---	278	185	46	395	7.2	---	--	---	---	---
132	Sequiota	8-64	2.47	17.8	7.4	.03	.00	67	3.8	10	1.9	200	0	14	14	.2	---	---	1.6	---	.00	226	183	18	409	7.6	---	--	---	---	---
		5-72	3.76	16.5	9.1	.40	.02	75	2.1	7.4	1.1	204	0	13	15	.0	---	---	1.7	---	---	244	162	34	380	7.2	5.8	59	7000	1600	5000
		10-72	12.3	14.5	11	.14	.02	86	2.1	7.2	1.3	268	0	11	12	.1	---	---	3.9	---	---	308	217	5.6	510	7.2	6.6	64	8000	740	400
		6-73	2.3	17.5	---	---	---	--	---	---	---	244	0	---	---	---	---	---	---	---	---	---	---	---	465	6.9	5.4	56	---	4300	100
		10-73	1.62	15.5	---	---	---	--	---	---	---	256	0	---	---	---	---	---	---	---	---	---	---	---	470	7.0	6.2	62	---	3400	340
		3-74	3.36	13.5	14	.11	.00	81	2.6	7.3	1.4	252	0	9.0	14	.0	.09	.12	3.3	.9	.10	289	204	10	478	7.4	---	--	---	3800	410
		8-74	2.3	17.0	---	---	---	75-	4.1	---	---	---	--	---	14	---	.33	.18	2.1	---	.14	---	---	---	460	7.0	5.8	60	---	---	---

Table 6 (continued).....

Map number (pl. 3)	Spring	Date of collection	Discharge (ft^3/s)	Temperature (°C)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Organic nitrogen as N	Ammonia nitrogen as N	Nitrate as N	Dissolved organic carbon	Total phosphorous as P	Dissolved solids (residue at 180°)	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	Specific conductance (μ mhos/cm at 25°C)	pH (units)	Dissolved oxygen: Milligrams per liter	Dissolved oxygen: Percent saturation	Colonies per 100 millilitres: Total coliform	Colonies per 100 millilitres: Fecal coliform	Colonies per 100 millilitres: Fecal streptococci
												White River basin--continued																			
139	Ward	9-64	1.73	15.0	9.3	.00	.00	73	2.4	5.1	2.0	207	0	9.2	7.5	0.1	---	---	4.7	---	.02	232	192	22	405	7.8	---	--	---	---	---
		5-72	3.77	14.0	11	.36	.01	73	1.4	4.8	1.0	190	0	7.3	9.2	.0	---	---	3.1	---	---	232	154	35	350	7.3	8.1	78	---	1100	2500
		10-72	7.64	14.5	11	.27	.03	76	1.5	4.8	1.1	200	0	7.4	9.2	.1	---	---	4.5	---	---	253	166	31	394	7.2	7.5	73	1900	65	110
		6-73	3.1	14.5	---	---	---	--	---	---	---	216	0	---	---	---	---	---	---	---	---	---	---	---	422	6.8	7.7	75	---	200	120
		10-73	1.96	15.5	---	---	---	--	---	---	---	232	0	---	---	---	---	---	---	---	---	---	---	---	425	7.2	8.0	80	---	230	970
		3-74	3.93	12.5	13	.11	.01	73	1.2	4.7	1.2	206	0	7.6	9.2	.1	.04	.10	4.1	1.0	.05	244	161	27	390	7.5	---	---	---	56	18
131	Winoka	11-64	.42	15.0	5.2	.20	.00	88	2.1	(9.6)		237	0	5.7	10	.0	---	---	5.0	---	---	276	228	33	390	7.4	---	--	---	---	---

Note: Temperature, specific conductance, and dissolved oxygen are field determinations.
Bicarbonate, carbonate and pH are also field determinations from 1972 to present.

SURFACE WATER

The primary objective of surface-water data collection in the project area was to provide information on streamflow characteristics for all major streams. To accomplish this, data were collected at continuous-record gaging stations, low-flow partial-record stations, and at numerous miscellaneous sites throughout the area (pl. 1 and tbl. 7). These data will be useful for many purposes, such as control of pollution; location and design of water-supply reservoirs, treatment plants, and industrial plants; design of highway bridges and culverts; management of floodplains; development of recreational facilities; and flood control.

Table 7 is a cross reference to all hydrologic data for streams and springs in the area and includes seepage-run measurements made during the project, miscellaneous measurements made during significant hydrologic events of the past, references to interpretive hydrologic data and analyses in other parts of the report, and descriptive remarks about hydrologic conditions of stream reaches and springs. The table will be of particular value to those who wish to make their own analyses of the data for a particular stream, stream reach or spring, and who need to locate available hydrologic data for their areas of interest.

For those who need basic hydrologic data from the continuous-record discharge and water-quality stations shown in the table (map nos. 74, 78, 107, 130, 134, 145, 147, 148, 151, 174, 204), see "Water Resources Data for Missouri, Part 1 and 2", an annual U.S. Geological Survey open-file report.

Table 7

HYDROLOGIC DATA FOR STREAMS AND SPRINGS

Map number (pl. 1)	Station name	Location	Date	Discharge (ft^3/s)	Conductance (µ mhos/cm @ 25°C)	Water temperature (°C)	Air temperature (°C)	Remarks
1	Hayes Spring	NE 1/4 NE 1/4 SW 1/4 sec. 19, T. 29 N., R. 23 W., in channel of Sac River, 7.5 mi west of Springfield, Greene County.	-----	-----	-----	-----	-----	([1] [2]).
2	Silverthorn Spring	SE 1/4 SW 1/4 NE 1/4 sec. 18, T. 29 N., R. 23 W., east of County Highway T, 0.75 mi north of State Highway 266 and 7.5 mi west of Springfield, Greene County.	-----	-----	-----	-----	----	([1]).
3	Sac River	SW 1/4 sec. 24, T. 29 N., R. 24 W., at bridge on county road 6 mi northwest of Republic, Greene County.	11-17-71 8-22-74	1.7 4.1	420 400	14.5 22.0	----- -----	----- ([3]).
4	Pond Creek	NE 1/4 NE 1/4 sec. 4, T. 28 N., R. 23 W., at bridge on county highway, 1 mi west of Brookline, Greene County.	11-17-71	0	-----	-----	-----	-----
5	Pond Creek Tributary	SW 1/4 SW 1/4 sec. 3, T. 28 N., R. 23 W., at bridge on county highway, 1 mi southwest of Brookline, Greene County.	11-17-71	0	-----	-----	-----	-----
6	Pond Creek	SW 1/4 NW 1/4 sec. 4, T. 28 N., R. 23 W., at bridge on county road, 2 mi west of Brookline, Greene County.	11-17-71	.01	420	14.5	-----	-----
7	Pond Creek	SE 1/4 NE 1/4 sec. 5, T. 28 N., R. 23 W., at bridge on county road, 2.5 mi west of Brookline, Greene County.	11-17-71	0.05	-----	-----	-----	-----
8	Pond Creek	SW 1/4 SW 1/4 sec. 32, T. 29 N., R. 23 W., at bridge on County Highway N, 3 mi west of Brookline, Greene County.	11-17-71 2-19-75	.2 8.2	420 340	14.5 11.0	----- 9.0	Abundant watercress at this site.
9	Pond Creek	E 1/2 sec. 25, T. 29 N., R. 24 W., at ford on county highway, 4 mi south of Bois D'Arc, Greene County.	11-17-71	0	-----	-----	-----	-----
10	Pond Creek	NW 1/4 sec. 25, T. 29 N., R. 24 W., at bridge on county highway, 3.5 mi south of Bois D'Arc, Greene County.	11-17-71 2-19-75	0 6.1	----- 330	----- 9.0	----- 7.5	On 2-19-75, flow estimated at mouth of Pond Creek was 9 ft^3/s.
11	Sac River	SW 1/4 SW 1/4 sec. 24, T. 29 N., R. 24 W., at bridge on State Highway 266, 3.5 mi south of Bois D'Arc, Greene County.	12-10-74	21.9	405	10.5	18.0	-----
12	Sac River	NW 1/4 sec. 23, T. 29 N., R. 24 W., at bridge on county highway, 2.5 mi south of Bois D'Arc, Greene County.	8-23-74 12-10-74	2.5 23.2	----- 415	----- 9.0	----- -----	----- -----
13	Pickerel Creek	SW 1/4 NW 1/4 sec. 22, T. 28 N., R. 24 W., at bridge on State Highway 174, 3 mi west of Republic, Greene County.	11-17-71	0	-----	-----	-----	-----
14	Trogdon Spring	NW 1/4 NE 1/4 sec. 21, T. 28 N., R. 24 W., about 0.4 mi north of State Highway 174 and 4 mi north of Billings, Greene County.	2-21-75	3.4	360	12.0	9.5	Trogdon Spring discharges about 1 to 2 ft^3/s during low-flow periods.
15	Pickerel Creek	SE 1/4 SW 1/4 sec. 10, T. 28 N., R. 24 W., at bridge on county highway, 3.5 mi northwest of Republic, Greene County.	11-17-71 12-11-74 2-19-75	0 14.1 8.0	----- 350 345	----- 8.0 7.0	----- 4.5 9.0	Flow from Trogdon Spring disappeared into streambed just upstream from bridge on 11-17-71.
16	Pickerel Creek Tributary near Republic	NW 1/4 SE 1/4 sec. 23, T. 28 N., R. 24 W., at culvert under State Highway 174, 2.0 mi west of Republic, Greene County.	-----	-----	-----	-----	-----	([4]).
17	Pickerel Creek	SW 1/4 SW 1/4 sec. 2, T. 28 N., R. 24 W., at bridge on County Highway TT, 4 mi northwest of Republic, Greene County.	11-17-71	0	-----	-----	-----	-----
18	Pickerel Creek	SE 1/4 SW 1/4 sec. 35, T. 29 N., R. 24 W., at bridge on county road, 2 mi southeast of Plano, Greene County.	12-11-74 2-18-75	18.1 14.4	410 340	9.0 9.5	5.5 2.5	The conductance of 12-11-74 appeared high but was checked and found to be accurate.

See footnotes at end of Table.

Table 7 (continued).....

Map number (pl. 1)	Station name	Location	Date	Discharge (ft^3/s)	Conductance (μ mhos/cm @ 25°C)	Water temper-ature (°C)	Air temper-ature (°C)	Remarks
19	Pickerel Creek	SW 1/4 SW 1/4 sec. 26, T. 29 N., R. 24 W., at Interstate Highway I-44, 1.2 mi southeast of Plano, Greene County.	2-18-75	11.8	330	8.5	1.5	-----
20	Dry Branch Tributary	SE 1/4 sec. 12, T. 28 N., R. 24 W., at bridge on county highway, 1 mi northwest of Republic, Greene County.	11-17-71	0	-----	-----	-----	-----
21	Dry Branch	NE 1/4 NW 1/4 sec. 7, T. 28 N., R. 23 W., at bridge on County Highway TT, 1 mi north of Republic, Greene County.	11-17-71 12-10-74 2-19-75	0 0 0	----- ----- -----	----- ----- -----	----- ----- -----	----- ----- -----
22	Dry Branch	SW 1/4 NW 1/4 sec. 6, T. 28 N., R. 23 W., at bridge on county highway, 2.5 mi northwest of Republic, Greene County.	2-19-75	0	-----	-----	-----	Pools of water; this was site where flow began on this date.
23	Dry Branch	SW 1/4 SE 1/4 sec. 36, T. 29 N., R. 24 W., at bridge on county highway, 3 mi southeast of Plano, Greene County.	2-19-75	3.0	-----	-----	-----	-----
24	Dry Branch	SE 1/4 SW 1/4 sec. 26, T. 29 N., R. 24 W., at Interstate High-way I-44, 1.6 mi southeast of Plano, Greene County.	2-18-75	4.0	320	8.5	1.0	-----
25	Dry Branch	SE 1/4 SW 1/4 sec. 26, T. 29 N., R. 24 W., at confluence with Pickerel Creek, 1.3 mi south-east of Plano, Greene County.	2-18-75	4.0	-----	-----	-----	-----
26	Pickerel Creek	NE 1/4 SW 1/4 sec. 26, T. 29 N., R. 24 W., at bridge on county highway, 1.2 mi east of Plano, Greene County.	12-11-74 2-19-75	16.0 14.4	350 340	9.0 6.0	7.0 -3.0	----- -----
27	Pickerel Creek (low-flow station 06918410)	NW 1/4 sec. 26, T. 29 N., R. 24 W., at bridge on State Highway 266, 1.5 mi northeast of Plano, Greene County.	11-17-71 2-18-75	0 13.7	----- 330	----- 8.0	----- 2.5	Discontinued low-flow station. Measured 600 ft downstream from bridge on 2-18-75.[2]
28	Pickerel Creek	NE 1/4 SE 1/4 sec. 22, T. 29 N., R. 24 W., about 0.7 mi down-stream from State Highway 266, 1.5 mi northeast of Plano, Greene County.	12-11-74 2-19-75	16.7 12.2	----- 340	----- 7.0	----- 7.5	----- -----
29	Pickerel Creek	NW 1/4 NE 1/4 sec. 22, T. 29 N., R. 24 W., 300 ft southwest of county road, 1.5 mi north of Plano, Greene County.	8-23-74 2-19-75	0 12.2	----- 340	----- 7.0	----- -2.0	----- -----
30	Pickerel Creek Tributary	NW 1/4 NE 1/4 sec. 22, T. 29 N., R. 24 W., in field about 500 ft southwest of county highway, 6 mi northwest of Republic, Greene County.	8-23-74 2-19-75	3.0 18.6	----- 350	----- 12.0	----- -1.0	Series of springs rise in small tributary. Pools in Pickerel Creek mark the be-ginning of peren-nial flow in the creek during dry weather.
31	Pickerel Creek	NW 1/4 SW 1/4 sec. 15, T. 29 N., R. 24 W., 1,500 ft upstream from county highway bridge, 6.5 mi northwest of Republic, Greene County.	8-22-74 12-10-74 2-18-75	14.0 42.8 41.1	410 390 380	18.0 12.0 9.5	----- ----- 3.5	([3]).
32	Pickerel Creek Tributary	NE 1/4 SE 1/4 sec. 16, T. 29 N., R. 24 W., 200 ft upstream from county highway bridge, 6.5 mi northwest of Republic, Greene County.	8-22-74	.3	480	15.5	-----	([3]).
33	Sac River	SW 1/4 SW 1/4 sec. 5, T. 29 N., R. 24 W., at bridge on County Highway F, 5 mi south of Ash Grove, Greene County.	11-17-71	12.0	420	14.0	-----	-----
34	Sycamore Creek	SW 1/4 sec. 6, T. 29 N., R. 24 W., at ford on county highway, 5 mi south of Ash Grove, Greene County.	11-17-71	.2	440	15.0	-----	-----

See footnotes at end of Table.

Table 7 (continued).....

Map number (pl. 1)	Station name	Location	Date	Discharge (ft³/s)	Conductance (µ mhos/cm @ 25°C)	Water temper-ature (°C)	Air temper-ature (°C)	Remarks
35	Dry Branch	SW 1/4 SW 1/4 sec. 21, T. 30 N., R. 24 W., at bridge on County Highway F at Ash Grove, Greene County.	11-17-71	0	-----	-----	-----	-----
36	Sac River (low-flow station, 06918420)	SE 1/4 sec. 18, T. 30 N., R. 24 W., at bridge on U.S. Highway 160, 1 mi northwest of Ash Grove, Greene County.	11-17-71	16.0	440	14.0	20.5	([2]).
37	Clear Creek	SW 1/4 SW 1/4 sec. 3, T. 29 N., R. 23 W., at bridge on County Highway EE, 2.5 mi west of Springfield, Greene County.	11-16-71	0	-----	-----	-----	-----
38	Clear Creek Spring	SW 1/4 SW 1/4 sec. 3, T. 29 N., R. 23 W., 0.5 mi west of County Highway AB, 0.75 mi north of County Highway EE, 3 mi west of Springfield, Greene County.	-----	-----	-----	-----	-----	([1]).
39	Clear Creek	NW 1/4 sec. 4, T. 29 N., R. 23 W., at bridge on county highway, 2 mi southwest of Willard, Greene County.	1-16-71	2.2	390	16.0	-----	-----
40	Brower Spring	NW 1/4 sec. 4, T. 29 N., R. 23 W., at culvert on county highway 2 mi southwest of Willard, Greene County.	8-22-74	.6	440	15.0	-----	([3]).
41	Rainer Branch	S 1/2 sec. 35, T. 30 N., R. 23 W., at bridge on County Highway AB, 1.5 mi south of Willard, Greene County.	11-16-71	0	-----	-----	-----	Scattered pools in channel; scum on water surface.
42	Clear Creek	SW 1/4 SE 1/4 sec. 29, T. 30 N., R. 23 W., at bridge on county highway, 5 mi southeast of Ash Grove, Greene County.	8-22-74	8.7	385	22.0	-----	([3]).
43	Clear Creek	SE 1/4 SE 1/4 sec. 19, T. 30 N., R. 23 W., at bridge on County Highway UU, 3.5 mi west of Willard, Greene County.	11-16-71	5.0	420	15.0	-----	-----
44	Sawdey Branch	On line between secs. 19 and 30, T. 30 N., R. 23 W., at bridge on county highway 3.5 mi west of Willard, Greene County.	11-16-71	.3	-----	-----	-----	-----
45	Clear Creek	SW 1/4 SW 1/4 sec. 2, T. 30 N., R. 24 W., at bridge on county highway, 1 mi south of Phenix, Greene County.	11-17-71	7.5	440	13.0	-----	-----
46	Clear Creek (low-flow station, 06918430)	SE 1/4 sec. 32, T. 31 N., R. 24 W., at bridge on county highway, 2.5 mi west of Phenix, Greene County.	11-17-71	9.7	460	13.0	19.5	([2]).
47	Clear Creek Tributary	NW 1/4 sec. 33, T. 31 N., R. 24 W., at bridge on County Highway V, 2 mi west of Phenix, Greene County.	11-17-71	0.2	-----	-----	-----	-----
48	Sac River	On line between secs. 30 and 31, T. 31 N., R. 24 W., at bridge on county highway, 4 mi west of Phenix, Greene County.	11-17-71	34.0	450	13.0	-----	-----
49	Burney Branch	SW 1/4 sec. 18, T. 31 N., R. 24 W., at bridge on County Highway U, 4 mi west of Walnut Grove, Greene County.	11-17-71	.6	500	14.0	-----	-----
50	J. Hart Spring	NW 1/4 NW 1/4 sec. 18, T. 28 N., R. 24 W., 1 mi south of County Highway TT, 2 mi west of County Highway PP, 6 mi west of Republic, Greene County.	-----	-----	-----	-----	-----	([1 2]).
51	Little Sac River	SE 1/4 NE 1/4 sec. 20, T. 30 N., R. 20 W., at bridge on county highway, 3 mi northwest of Strafford, Greene County.	11-16-71	.4	370	12.0	-----	-----
52	Little Sac River Tributary	On line between secs. 28 and 29, T. 30 N., R. 20 W., at bridge on county highway, 2 mi northwest of Strafford, Greene County.	11-16-71	0	-----	-----	-----	-----

See footnotes at end of Table.

Table 7 (continued).....

Map number (pl. 1)	Station name	Location	Date	Discharge (ft^3/s)	Conductance (μ mhos/cm @ 25°C)	Water temperature (°C)	Air temperature (°C)	Remarks
53	Little Sac River Tributary	SE 1/4 NE 1/4 sec. 25, T. 30 N., R. 21 W., at bridge on County Highway AA, 4.5 mi northwest of Strafford, Greene County.	11-16-71	0	-----	-----	-----	-----
54	Little Sac River	SE 1/4 sec. 17, T. 30 N., R. 21 W., at bridge on U.S. Highway 65, 4.5 mi north of Springfield, Greene County.	11-16-71	2.9	360	13.0	-----	-----
55	Little Sac River	SW 1/4 sec. 26, T. 30 N., R. 22 W., at bridge on State Highway 13, 2 mi north of Springfield, Greene County.	11-16-71	0	-----	-----	-----	Pools of water; no surface flow.
56	South Dry Sac Creek	SE 1/4 NE 1/4, sec. 3, T. 29 N., R. 21 W., at bridge on county highway, 1.5 mi northeast of Springfield, Greene County.	11-16-71	0	-----	-----	-----	-----
57	South Dry Sac Creek Tributary	On line between secs. 4 and 34, T. 29 and 30 N., R. 21 W., at bridge on county highway 1.5 mi north of Springfield, Greene County.	11-16-71	0	-----	-----	-----	-----
58	South Dry Sac Creek Tributary	S 1/2 sec. 4, T. 29 N., R. 21 W., at bridge on county highway, 1 mi north of Springfield, Greene County.	11-16-71	0	-----	-----	-----	-----
59	South Dry Sac Creek	N 1/2 sec. 5, T. 29 N., R. 21 W., at bridge on county highway, 0.5 mi north of Springfield, Greene County.	11-16-71	1.9	420	12.5	12.0	Discharge primarily outflow from series of springs and seeps in vicinity of Valley Water Mills.
			8-22-74	2.8	370	19.0	-----	([3]).
60	South Dry Sac Creek	SE 1/4 sec. 32, T. 30 N., R. 21 W., at bridge on U.S. Highway 65, 1 mi north of Springfield, Greene County.	11-16-71	0	-----	-----	-----	-----
61	Fulbright Spring	SW 1/4 NW 1/4 sec. 2, T. 29 N., R. 22 W., 1.3 mi north of Interstate Highway I-44, 0.5 mi east of State Highway 13, Greene County.	-----	-----	-----	-----	-----	([1,2]).
62	South Dry Sac Creek	NW 1/4 sec. 35, T. 30 N., R. 22 W., at bridge on State Highway 13, 1.5 mi north of Springfield, field, Greene County.	11-16-71	10.0	540	17.5	22.0	Site is downstream from Northwest Sewage Treatment Plant and Water Works. Water murky from light-colored colloidal suspension. Caused by cleaning filters at water plant.
63	Spring Branch	NE 1/4 NW 1/4 sec. 4, T. 29 N., R. 22 W., at bridge on county highway, 1.5 mi northwest of Springfield, Greene County.	9-26-53	1.1	-----	20.0	-----	-----
			11-16-71	2.2	560	16.5	-----	Creek is spring-fed (by Ritter Springs). ([3]).
			8-22-74	5.0	540	15.5	-----	
64	Williams Spring	NW 1/4 NE 1/4 NE 1/4 sec. 33, T. 30. N. R. 22 W., 2.5 mi northwest of Springfield, Greene County.	-----	-----	-----	-----	-----	([1,2]).
65	Little Sac River	SW 1/4 sec. 20, T. 30 N., R. 22 W., at bridge on County Highway O, 2 mi east of Willard, Greene County.	11-16-71	7.9	600	16.0	22.0	-----
66	Flint Hill Branch	SE 1/4 SE 1/4 sec. 5, T. 30 N., R. 22 W., at bridge on county highway, 5 mi east of Cave Spring, Greene County.	11-16-71	0	-----	-----	-----	This is approximate point where flow begins in this tributary.
67	Flint Hill Branch	NW 1/4 sec. 5, T. 30 N., R. 22 W., at bridge on county highway, 4.5 mi east of Cave Spring, Greene County.	11-16-71	1.2	480	15.5	-----	-----
68	Little Sac River	NW 1/4 SE 1/4 sec. 24, T. 31 N., R. 23 W., at bridge on County Highway BB, 1 mi east of Sacville, Greene County.	11-16-71	13.0	570	14.5	17.0	-----

See footnotes at end of Table.

Table 7 (continued).....

Map number (pl. 1)	Station name	Location	Date	Discharge (ft^3/s)	Conductance (μ mhos/cm @ 25°C)	Water temperature (°C)	Air temperature (°C)	Remarks
69	North Dry Sac Creek	NW 1/4 sec. 20, T. 31 N., R. 21 W., at bridge on County Highway H, 2 mi northwest of Fruitland, Greene County.	11-16-71	0	-----	-----	-----	Scattered pools but no flow on surface.
70	Sims Branch	NE 1/4 sec. 31, T. 31 N., R. 21 W. at bridge on county highway, 2 mi northwest of Fruitland, Greene County.	11-16-71	<0.05	-----	-----	-----	-----
71	Sims Branch	SE 1/4 sec. 23, T. 31 N., R. 22 W., at bridge on County Highway CC, 4.5 mi west of Fruitland, Greene County.	11-16-71	.3	450	13.5	-----	-----
72	North Dry Sac Creek	NE 1/4 NE 1/4 sec. 22, T. 31 N., R. 22 W., at bridge on county highway, 4.5 mi east of Sacville, Greene County.	11-16-71	2.9	420	15.0	19.0	-----
73	King Branch	SW 1/4 sec. 23, T. 31 N., R. 22 W., at bridge on County Highway CC, 4.5 mi east of Sacville, Greene County.	11-16-71	<0.05	-----	-----	-----	-----
74	Oak Grove Branch (continuous-record station 06918700)	SE 1/4 NW 1/4 sec. 21, T. 31 N., R. 22 W., at culvert under County Highway BB, 4 mi south of Brighton, Greene County.	1956 to current year	-----	-----	-----	-----	-----
75	Cave Spring	SE 1/4 sec. 4, T. 30 N., R. 23 W., at Cave Spring, Greene County.	8-22-74	0.3	490	14.0	-----	([1] [2] [3]).
76	Asher Creek	NW 1/4 sec. 16, T. 31 N., R. 23 W., at bridge on county highway, 4 mi northeast of Walnut Grove, Greene County.	11-17-71	2.5	460	12.5	-----	-----
77	Asher Creek Tributary	NE 1/4 sec. 17, T. 31 N., R. 23 W., at bridge on county highway, 3.5 mi northeast of Walnut Grove, Greene County.	11-17-71	1.3	450	12.0	-----	-----
78	Little Sac River (continuous-record station 06918740)	SW 1/4 SW 1/4 sec. 20, T. 32 N., R. 23 W., bridge on State Highway 215, 3 mi west of Morrisville, Polk County.	1968 to current year	-----	-----	-----	-----	([2]).
79	Franca Branch	NW 1/4 SE 1/4 sec. 16, T. 32 N., R. 22 W., just upstream from culvert under State Highway 13, 3 mi north of Brighton, Polk County.	-----	-----	-----	-----	-----	([4]).
80	Pomme de Terre River	SW 1/4 sec. 15, T. 30 N., R. 19 W., at bridge on county highway, 2 mi northwest of Northview, Webster County.	8-23-74	1.5	335	24.0	-----	([3]).
81	North Fork Pomme de Terre River	SW 1/4 sec. 4, T. 30 N., R. 19 W., at bridge on county highway, 5 mi northwest of Northview, Webster County.	8-23-74	0.3	400	23.0	-----	-----
82	South Fork Pomme de Terre River	NE 1/4 SE 1/4 sec. 13, T. 30 N., R. 20 W., at bridge on county highway, 4 mi northeast of Strafford, Greene County.	8-23-74	3.5	315	24.0	-----	([3]).
83	Pomme de Terre River	NW 1/4 NW 1/4 sec. 1, T. 30 N., R. 20 W., at bridge on county highway, 4.5 mi southeast of Fair Grove, Greene County.	11-15-71 8-23-74	3.5 6.0	410 360	16.0 24.5	----- -----	----- ([3]).
84	Pomme de Terre River Tributary	NW 1/4 NW 1/4 sec. 1, T. 30 N., R. 20 W., at bridge on county highway, 4 mi southeast of Fair Grove, Greene County.	11-15-71	0	-----	-----	-----	-----
85	Pomme de Terre River	SW 1/4 NE 1/4 sec. 27, T. 31 N., R. 20 W., at bridge on County Highway E, 1.5 mi east of Fair Grove, Greene County.	11-15-71	4.8	440	17.0	25.0	-----
86	Selph Branch	SE 1/4 SE 1/4 sec. 15, T. 31 N., R. 20 W., at bridge on county highway, 2 mi northeast of Fair Grove, Greene County.	11-15-71	0.05	500	17.0	-----	-----

See footnotes at end of Table.

Table 7 (continued).....

Map number (pl. 1)	Station name	Location	Date	Discharge (ft^3/s)	Conductance (µ mhos/cm @ 25°C)	Water temper-ature (°C)	Air temper-ature (°C)	Remarks
87	Mutton Hollow	NE 1/4 NE 1/4 sec. 15, T. 31 N., R. 20 W., at bridge on county highway, 3 mi northeast of Fair Grove, Greene County.	11-15-71	0.2	440	20.0	-----	-----
88	Pomme de Terre River	NW 1/4 sec. 15, T. 31 N., R. 20 W., at bridge on county highway, 2.5 mi northeast of Fair Grove, Greene County.	11-15-71	5.7	440	15.0	23.0	-----
89	Little Pomme de Terre River	SE 1/4 sec. 4, T. 30 N., R. 20 W., at bridge on County Highway KK, 2 mi southeast of Fair Grove, Greene County.	11-15-71	0.05	-----	-----	-----	-----
90	Little Pomme de Terre River	SE 1/4 NE 1/4 sec. 6, T. 30 N., R. 20 W., at bridge on county highway, 2 mi southwest of Fair Grove, Greene County.	8-23-74	.3	395	22.5	-----	(3).
91	Little Pomme de Terre River	SW 1/4 sec. 30, T. 31 N., R. 20 W., at bridge on county highway, 1 mi southwest of Fair Grove Greene County.	11-15-71	1.0	390	17.5	-----	-----
92	Little Pomme de Terre River	NE 1/4 NE 1/4 sec. 25, T. 31 N., R. 21 W., at bridge on County Highway CC, 1 mi west of Fair Grove, Greene County.	11-15-71	2.0	420	17.0	-----	-----
93	Little Pomme de Terre River	E 1/2 sec. 13, T. 31 N., R. 21 W., at bridge on county highway, 2 mi northwest of Fair Grove, Greene County.	11-15-71	2.5	-----	-----	-----	-----
94	James River Tributary	SW 1/4 sec. 24, T. 29 N., R. 17 W., at low-water ford on County Highway V, 3 mi northeast of Seymour, Webster County.	9-11-73 8-19-74	.05 .05	350 374	22.0 18.0	----- -----	----- -----
95	James River	NE 1/4 NW 1/4 sec. 21, T. 29 N., R.17 W., at low-water ford on county highway, 3 mi northeast of Diggins, Webster County.	9-11-73 8-19-74	1.0 2.5	340 360	23.0 19.0	27.0 -----	----- -----
96	James River	SE 1/4 NE 1/4 sec. 3, T. 29 N., R. 18 W., at bridge on County Highway A, 5 mi northwest of Diggins, Webster County.	8-19-74	3.4	320	22.0	-----	(3).
97	Turnbo Creek	SE 1/4 sec. 35, T. 30 N., R. 19 W., at low-water ford on county highway, 1 mi southeast of Northview, Webster County.	9-11-73 8-19-74	.2 .4	320 370	27.0 24.0	25.0 -----	----- -----
98	James River (low-flow station, 07050540)	NW 1/4 sec. 3, T. 29 N., R. 19 W., at bridge on County Highway B, 1.5 mi south of Northview, Webster County.	9-1-54 9-11-73	0.2 3.0	----- 320	----- 24.0	----- 23.0	(2). -----
99	North Carolina Creek	SW 1/4 NW 1/4 sec. 3, T. 29 N., R. 19 W., at bridge on County Highway B, 2 mi southwest of Northview, Webster County.	9-11-73	0	-----	-----	-----	Scattered pools in creek - no flow.
100	Dry Fork Creek	SW 1/4 sec. 34, T. 29 N., R. 19 W., at bridge on County Highway PP, 3.5 mi west of Fordland, Webster County.	9-11-73	0	-----	-----	-----	-----
101	Dry Fork Creek	SE 1/4 sec. 28, T. 29 N., R. 19 W., at low-water ford on county highway, 4 mi northwest of Fordland, Webster County.	9-11-73	.2	-----	-----	-----	-----
102	Panther Creek	SE 1/4 sec. 21, T. 29 N., R. 19 W., at bridge on County Highway KK, 5 mi northwest of Fordland, Webster County.	9-11-73	0	-----	-----	-----	One small pool of water in channel.
103	Panther Creek	NW 1/4 sec. 21, T. 29 N., R. 19 W., about 0.3 mi east of Antioch Church, 5.5 mi northwest of Fordland, Webster County.	9-11-73	.2	-----	-----	-----	Irrigation equipment located at this site.
104	Panther Creek (low-flow station, 07050560)	NW 1/4 sec. 17, T. 29 N., R. 19 W., at low-water ford on County Highway B, 6 mi northwest of Fordland, Webster County.	9-11-73 8-19-74	0.9 4.0	330 342	23.0 22.0	25.0 -----	----- (2 3).

See footnotes at end of Table.

Table 7 (continued).....

Map number (pl. 1)	Station name	Location	Date	Discharge (ft^3/s)	Conductance (µmhos/cm @ 25°C)	Water temper-ature (°C)	Air temper-ature (°C)	Remarks
105	Davis Creek	SW 1/4 sec. 1, T. 29 N., R. 20 W., at ford on county highway, 3 mi southeast of Strafford, Greene County.	9-11-73	0	-----	-----	-----	-----
106	James River	SE 1/4 SW 1/4 sec. 13, T. 29 N., z R. 20 W., at bridge on county highway, 5 mi southeast of Strafford, Greene County.	9-1-54	.05	-----	-----	-----	-----
107	James River (continuous-record station, 07050580)	NW 1/4 sec. 24, T. 29 N., R. 20 W., at bridge on county highway, 5 mi southeast of Strafford, Greene County.	1973 to current year	-----	-----	-----	-----	-----
			8-19-74	11.0	325	22.0	-----	-----
108	Broad Creek	NW 1/4 NE 1/4 sec. 22, T. 29 N., R. 20 W., at ford on county highway, 4 mi south of Strafford, Greene County.	9-11-73	0	-----	-----	-----	-----
109	Sawyer Creek	On line between secs. 36 and 1, T. 29 N., and 28 N, R. 20 W., at bridge on county highway, 3 mi north of Rogersville, Greene County.	9-11-73	0	-----	-----	-----	-----
110	Sawyer Creek	NW 1/4 sec. 26, T. 29 N., R. 20 W., at bridge on county highway, 5 mi northwest of Rogersville Greene County.	9-11-73	1.5	360	21.0	22.0	-----
			8-19-74	1.1	352	21.0	-----	(3).
111	James River	SE 1/4 SW 1/4 sec. 21, T. 29 N., R. 20 W., at bridge on State Highway 125, 5 mi south of Strafford, Greene County.	9-1-54	0	-----	-----	-----	Long, shallow pool extended 300 ft upstream. About 0.05 ft^3/s flowing from pool into gravel.
			9-12-73	7.4	330	21.0	18.0	-----
			8-20-74	18.0	330	21.0	-----	(3).
112	Little Yosemite Spring	SE 1/4 NW 1/4 sec. 28, T. 29 N., R. 20 W., 0.25 mi west of State Highway 125, 0.5 mi southeast of James River, and 5 mi south of Strafford, Greene County.	12-12-74	.9	335	13.0	-----	-----
113	Unnamed Spring	SE 1/4 NW 1/4 sec. 28, T. 29 N., R. 20 W., 0.25 mi west of State Highway 125, 0.5 mi southeast of James River, and 5 mi south of Strafford, Greene County.	12-12-74	.3	310	10.5	-----	-----
114	James River	NW 1/4 NW 1/4 sec. 31, T. 29 N., R. 20 W., at bridge on County Highway D, 3 mi east of Springfield, Greene County.	9-1-54	.2	-----	-----	-----	-----
			9-12-73	10.0	320	22.0	17.0	-----
115	Turner Creek	NE 1/4 NE 1/4 sec. 4 T. 28 N., R. 20 W., at bridge on State Highway 125, 4.5 mi northwest of Rogersville, Greene County.	9-11-73	0	-----	-----	-----	-----
116	Turner Creek	SW 1/4 SW 1/4 sec. 28, T. 29 N., R. 20 W., at railroad bridge, 1 mi southeast of Turner, Greene County.	9-11-73	1.0	-----	-----	-----	-----
117	Turner Creek	SW 1/4 SW 1/4 sec. 29, T. 29 N., R. 20 W., at bridge on county highway at Turner, Greene County.	9-11-73	1.1	370	19.0	-----	-----
			8-20-74	1.7	365	18.5	-----	(3).
118	Pearson Creek	SW 1/4 sec. 5, T. 29 N., R. 20 W., at bridge on county highway, 4 mi east of Springfield, Greene County.	9-10-73	.5	-----	-----	-----	Branch choked with watercress.
119	Pearson Creek	NW 1/4 NW 1/4 sec. 8, T. 29 N., R. 20 W., at ford on county highway, 4 mi east of Springfield, Greene County.	8-20-74	3.6	400	16.0	-----	(3).
120	Pearson Creek	NE 1/4 NE 1/4 sec. 13, T. 29 N., R. 21 W., at bridge on County Highway YY, 3 mi east of Springfield, Greene County.	8-20-74	4.0	400	17.5	-----	-----
			2-20-75	11.1	330	9.0	5.0	-----
121	Pearson Creek	NW 1/4 NE 1/4 sec. 23, T. 29 N., R. 21 W., at low-water ford on county highway, 1.5 mi east Springfield, Greene County.	9-10-73	2.5	380	23.0	25.0	-----
			8-20-74	4.8	410	20.0	-----	(3).
			2-20-75	12.3	340	6.0	3.0	-----

See footnotes at end of Table.

Table 7 (continued).....

Map number (pl. 1)	Station name	Location	Date	Discharge (ft3/s)	Conductance (µ mhos/cm @ 25°C)	Water temper- ature (°C)	Air temper- ature (°C)	Remarks
122	Pearson Creek	SW 1/4 NW 1/4 sec. 23, T. 29 N., R. 21 W., at bridge on Cherry St. Road, 1 mi east of Springfield, Greene County.	9-10-73	0.4	-----	-----	-----	Flow disappears into gravel about 200 ft downstream from bridge when creek is interrupted.
			2-20-75	12.0	-----	-----	-----	
123	Pearson Creek	SW 1/4 sec. 23, T. 29 N., R. 21 W., adjacent to Cherry Valley Estates subdivision, 1 mi east of Springfield, Greene County.	9-10-73	0	-----	-----	-----	Stream dry in this area.
			8-20-74	0	-----	-----	-----	-----
			2-20-75	3.2	330	4.5	-3.0	Approximately 9 ft^3/s lost in a series of pools about 1/4 mi upstream.
124	Pearson Creek	SE 1/4 NW 1/4 sec. 26, T. 29 N., R. 21 W., at bridge on county highway, 1 mi east of Spring- field, Greene County.	9-10-73	1.0	390	19.0	23.0	Flow begins about 500 ft upstream from this site.
			8-20-74	1.5	415	18.0	-----	([3]).
			2-20-75	15.0	350	10.0	10.0	Flow is about 3 ft^3/s at site where spring and seep inflow begins, 500 ft upstream.
125	Jones Spring	SW 1/4 SW 1/4 NE 1/4 sec. 27, T. 29 N., R. 21 W., 0.75 mi north of County Highway D, 1 mi east of Springfield, Greene County.	-----	-----	-----	-----	-----	([1,2]).
126	Pearson Creek	SE 1/4 NW 1/4 sec. 26, T. 29 N., R. 21 W., 100 ft downstream from bridge on county high- way, 1 mi east of Springfield, Greene County.	9-10-73	2.0	390	19.0	23.0	Increase in flow on 9-10-73 is from right bank seepage into Pearson Creek from Jones Spring Valley. Jones Spring Branch was dry downstream from a series of impound- ments, but seepage into Pearson Creek was underflow from these impoundments. There was extensive algae growth in the area of seepage be- cause of pollution in Jones Spring. Conductance of water at the seep was 400 micromhos @ 25°C.
127	Pearson Creek	NW 1/4 NE 1/4 sec. 35, T. 29 N., R. 21 W., at bridge on County Highway D, 1.5 mi east of Springfield, Greene County.	9-1-54	.1	-----	-----	-----	-----
			9-10-73	2.7	380	22.0	27.0	-----
128	Pearson Creek	SW 1/4 NE 1/4 sec. 35, T. 29 N., R. 21 W., at railroad bridge, 0.75 mi upstream from the mouth and 1.5 mi east of Springfield, Greene County.	2-20-75	21.0	-----	-----	-----	-----
129	Pearson Creek	NE 1/4 sec. 2, T. 28 N., R. 21 W., at mouth of creek, 2 mi east of Springfield, Greene County.	9-10-73	4.0	440	21.0	23.0	-----
			8-20-74	9.6	450	21.0	-----	([3]).
130	James River (continuous- record station 07050700).	NE 1/4 NW 1/4 sec. 11, T. 28 N., R. 21 W., on county highway at Kinser Bridge, 2.5 mi southeast of Springfield, Greene County.	1955 to cur- rent year	-----	-----	-----	-----	-----
			9-10-73	14.0	-----	-----	-----	
			8-20-74	21.0	-----	-----	-----	-----
			2-20-75	179	-----	-----	-----	-----
131	Winoka Spring	NW 1/4 NW 1/4 sec. 22, T. 28 N., R. 21 W., 0.5 mi southeast of U.S. Highway 60-65 interchange in Springfield, Greene County.	-----	-----	-----	-----	-----	([2,4]).
132	Sequiota Spring	NE 1/4 NW 1/4 sec. 9, T. 28 N., R. 21 W., in Sequiota Park at Springfield,. Greene County.	8-20-74	2.3	460	17.0	-----	([1,2,3]).
133	Galloway Creek	SW 1/4 NE 1/4 sec. 16, T. 28 N., R. 21 W., at bridge on Business Route U.S. Highway 60 and 65 in Springfield, Greene County.	8-4-64	.4	-----	-----	-----	-----
			10-19-64	.6	-----	-----	-----	-----
			1-19-65	2.7	-----	-----	-----	-----
			4-27-65	7.3	-----	-----	-----	-----
134	James River continuous- record tempera- ture station	SE 1/4 NE 1/4 sec. 30, T. 28 N., R. 21 W., 4 miles northeast of Nixa and 1/2 mi southwest of Lake Springfield, Green County.	1966 to cur- rent year	-----	-----	-----	-----	-----
			8-13-75	12.5	-----	26.5	-----	-----

See footnotes at end of Table.

Table 7 (continued).....

Map number (pl. 1)	Station name	Location	Date	Discharge (ft^3/s)	Conductance (μ mhos/cm @ 25°C)	Water temperature (°C)	Air temperature (°C)	Remarks
135	Camp Cora Spring	NE 1/4 SE 1/4 sec. 30, T. 28 N., R. 21 W., approximately 0.5 mi downstream from Lake Springfield, about 75 ft from the James River, Greene County.	8-20-74	3.0	440	16.0	-----	([1 2 3]).
136	Maple Grove Branch (peak-flow station 07050800)	SW 1/4 NE 1/4 sec. 3, T. 27 N., R. 21 W., at culvert under County Highway NN, 3.4 mi north of Ozark, Christian County.	1957 to current year	-----	-----	-----	-----	([4]).
137	James River	NW 1/4 NW 1/4 sec. 36, T. 28 N., R. 22 W., at bridge on State Highway 160, 2 mi south of Springfield, Christian County.	9-1-54	0	-----	-----	-----	On 9-1-54, there was irrigation from pools in the channel on both sides of the bridge.
			8-13-75	14.3	-----	-----	-----	-----
138	James River	SW 1/4 NE 1/4 sec. 27, T. 28 N., R. 22 W., at bridge on County highway, 2 mi southeast of Battlefield, Greene County.	8-13-75	15.5	-----	-----	-----	-----
139	Ward Spring	SE 1/4 SE 1/4 sec. 14, T. 28 N., R. 22 W., 0.25 mi west of U.S. Highway 60, 1 mi south of County Highway M, Greene County.	-----	-----	-----	-----	-----	([1 2]).
140	Ward Branch	NE 1/4 sec. 23, T. 28 N., R. 22 W., at bridge on county highway, 1 mi south of Springfield, Greene County.	8-20-74	.5	-----	-----	-----	-----
141	Ward Branch	NE 1/4 sec. 22, T. 28 N., R. 22 W., at bridge on county highway, 2 mi south of Springfield, Greene County.	8-20-74	0	-----	-----	-----	-----
142	Ward Branch	NW 1/4 sec. 27, T. 28 N., R. 22 W., at bridge on county highway near the mouth, 2.5 mi south of Springfield, Greene County.	8-20-74	0	-----	-----	-----	-----
143	Blue Spring	NE 1/4 NE 1/4 sec. 32, T. 28 N., R. 22 W., about 300 ft from James River, 2 mi southeast of Battlefield, Christian County.	8-20-74	4.5	440	14.0	-----	([1 2 3]).
			8-13-75	3.4	-----	-----	-----	-----
144	James River (continuous-record station 07051500)	NE 1/4 sec. 32, T. 28 N., R. 22 W., at county highway bridge 2 mi southeast of Battlefield, Christian County.	1929-32	-----	-----	-----	-----	([2]).
			8-13-75	20.5	-----	-----	-----	-----
145	James River (water-quality record station 07051600)	SW 1/4 NW 1/4 sec. 5, T. 27 N., R. 22 W., at Nelson Mill Bridge on county road, 2.5 mi southeast of Wilson Creek and 2 mi upstream from Wilson Creek.	1967 to current year	-----	-----	-----	-----	-----
			8-12-75	21.1	-----	-----	-----	-----
146	Wilson Creek (continuous-record station 07052000)	NE 1/4 SE 1/4 sec. 28, T. 29 N., R. 22 W., at bridge on State Highway 88 downstream from Jordan Creek, 1 mi west of Springfield.	1933-39	-----	-----	-----	-----	([2]).
147	Wilson Creek (continuous-record station 07052100)	NE 1/4 NE 1/4 sec. 6, T. 28 N., R. 22 W., on right bank just downstream from bridge on county road, 1 mi upstream from Southwest Sewage Treatment plant of Springfield and South Creek, and in Springfield, Greene County.	1972 to current year	-----	-----	-----	-----	-----
148	Wilson Creek (continuous-record station 07052150)	SW 1/4 NE 1/4 sec. 7, T. 28 N., R. 22 W., 1,700 ft downstream from South Creek.	1968-72	-----	-----	-----	-----	([2 5]).
149	Rader Spring	SE 1/4 NW 1/4 sec. 18, T. 28 N., R. 22 W., on the west bank of Wilson Creek about 5 mi southwest of Springfield, Greene County.	-----	-----	-----	-----	-----	([1]).
150	Wilson Creek	SW 1/4 sec. 18, T. 28 N., R. 22 W., at bridge on county road, 3,000 ft downstream from Rader Spring.	-----	-----	-----	-----	-----	([5]).
151	Wilson Creek (continuous-record station 07052160)	NW 1/4 SW 1/4 sec. 24, T. 28 N., R. 23 W., at bridge on county road, 2,000 ft upstream from McElhaney Branch.	1968-70, 1972 to current year	-----	-----	-----	-----	([5]).

See footnotes at end of Table.

Table 7 (continued).....

Map number (pl. 1)	Station name	Location	Date	Discharge (ft^3/s)	Conductance (μ mhos/cm @ 25°C)	Water temperature (°C)	Air temperature (°C)	Remarks
152	Wilson Creek	NW 1/4 SW 1/4 sec. 25, T. 28 N., R. 23 W., at bridge on county road, 1,500 ft upstream from Shuyler Creek.	-----	-----	-----	-----	-----	([5]).
153	Shuyler Creek	NW 1/4 NE 1/4 sec. 27, T. 28 N., R. 23 W., at low-water bridge on county highway, 1.5 mi southeast of Republic, Greene County.	8-31-74 2-20-75	0.4 2.0	----- -----	----- -----	----- -----	([3]). On 2-20-75, flow decreased to about 0.2 ft3/s just upstream from Campground Spring.
154	Shuyler Creek	SE 1/4 SE 1/4 sec. 26, T. 28 N., R. 23 W., at ford on county highway near the mouth, 2 mi southwest of Battlefield, Greene County.	8-20-74 2-20-75	0 3.0	----- -----	----- -----	----- -----	On 8-20-74, there were scattered pools near the mouth.
155	Terrell Creek	SW 1/4 SW 1/4 sec. 1, T. 27 N., R. 24 W., at ford on county highway, 2 mi east of Billings, Christian County.	9-13-73 4-9-75	1.5 10.0	370 330	14.5 13.5	----- 21.5	Discharge was from spring branch and is beginning of perennial flow in Terrell Creek. No flow upstream from spring branch except during heavy precipitation.
156	Terrell Creek	NW 1/4 SE 1/4 sec. 1, T. 27 N., R. 24 W., at ford on County highway, 2.5 mi east of Billings, Christian County.	4-9-75	10.0	350	14.0	-----	-----
157	Terrell Creek	NW 1/4 SE 1/4 sec. 6, T. 27 N., R. 23 W., at ford on county highway, 3 mi east of Billings, Christian County.	9-13-73 4-9-75	0 6.0	----- 290	----- 17.5	----- -----	On 9-13-73, stream was completely dry in this reach. Conductance was rechecked for accuracy on 4-9-75.
158	Terrell Creek	NW 1/4 sec. 5, T. 27 N., R. 23 W., at bridge on County Highway P, 2.5 mi north of Clever, Christian County.	9-13-73 4-9-75	2.2 18.0	390 340	19.0 16.0	23.5 20.5	Watercress abundant. -----
159	Terrell Creek	SE 1/4 SW 1/4 sec. 33, T. 28 N., R.23 W., in pasture about 0.5 mi east of county highway, 3 mi north of Clever, Christian County.	9-13-73 4-9-75	.9 15.4	360 360	21.5 17.0	----- -----	On 9-13-73, discharge entered long pool and disappeared. Creek was dry to junction with Luce Branch.
160	Luce Branch	NW 1/4 NW 1/4 sec. 3, T. 27 N., R. 23 W., in pasture about 1.5 mi west of County Highway ZZ, 3 mi northeast of Clever, Christian County.	9-13-73 4-9-75	.3 7.5	440 370	20.0 16.0	----- -----	Watercress in channel. -----
161	Terrell Creek	SE 1/4 NW 1/4 NW 1/4 sec. 3, T. 27 N., R. 23 W., in pasture about 1.5 mi west of County Highway ZZ, 3 mi northeast of Clever, Christian County.	9-13-73 4-9-75	0.3 19.4	440 345	20.0 16.5	----- -----	On 9-13-73, flow ended about 200 ft downstream. Stream was dry from this point to Double Spring.
162	Terrell Creek	NE 1/4 NE 1/4 sec. 3, T. 27 N., R. 23 W., at transmission line crossing about 0.6 mi west of County Highway ZZ, 3 mi northeast of Clever, Christian County.	9-13-73 4-9-75	0 15.5	----- 345	----- 16.0	----- -----	----- -----
163	Unnamed Spring	SW 1/4 SW 1/4 sec. 35, T. 28 N., R. 23 W., in pasture about 0.4 mi west of County Highway ZZ, 3 mi northeast of Clever, Christian County.	9-13-73 4-9-75	0 4.0	----- 380	----- 11.5	----- 21.0	----- Abundant watercress in spring branch.
164	Terrell Creek	SE 1/4 SW 1/4 sec. 35, T. 28 N., R. 23 W., in pasture about 0.2 mi west of County Highway ZZ, 3 mi northeast of Clever, Christian County.	9-13-73 4-9-75	0 21.2	----- -----	----- -----	----- 21.0	----- -----
165	Double Spring	NE 1/4 NW 1/4 sec. 2, T. 27 N., R. 23 W., 1,000 ft west of County Highway ZZ, 5 mi northeast of Clever, Christian County.	9-13-73	1.9	420	18.0	21.0	Source of flow for lower Terrell Creek during dry weather.

See footnotes at end of Table.

Table 7 (continued).....

Map number (pl. 1)	Station name	Location	Date	Discharge (ft^3/s)	Conductance (μ mhos/cm @ 25°C)	Water temperature (°C)	Air temperature (°C)	Remarks
166	Terrell Creek	SE 1/4 SW 1/4 sec. 35 T. 28 N., R. 23 W., at bridge on County Highway ZZ, 5 mi northeast of Clever, Christian County.	9-13-73 8-20-74 4-9-75	1.9 6.5 29.0	420 420 390	18.0 20.0 11.5	21.0 ----- 21.0	----- ([3]). -----
167	Wilson Creek	On line between secs. 1 and 36, T. 27 and 28 N., R. 23 W., at Manley Ford, 1,500 ft downstream from Terrell Creek.	-----	-----	-----	-----	-----	([5]).
168	Porter Spring	SE 1/4 SE 1/4 NW 1/4 sec. 1, T. 27 N., R. 23 W., on right bank of Wilson Creek about 0.5 mi upstream from the James River, Christian County.	-----	-----	-----	-----	-----	([1]).
169	Green Valley Creek	NE 1/4 NE 1/4 SW 1/4 sec. 23, T. 27 N., R. 23 W., at ford on county road, 3 mi east of Clever, Christian County.	8-21-74	0	-----	-----	-----	-----
170	Green Valley Creek Tributary	NE 1/4 NW 1/4 NE 1/4 sec. 26, T. 27 N., R. 23 W., at ford on county road, 3.25 mi east of Clever, Christian County.	8-21-74	0	-----	-----	-----	-----
171	Green Valley Creek Tributary	SW 1/4 SE 1/4 SE 1/4 sec. 15, T. 27 N., R. 23 W., at ford on county road, 2 mi northeast of Clever, Christian County.	8-21-74	0	-----	-----	-----	-----
172	Green Valley Creek	SW 1/4 NE 1/4 SW 1/4 sec. 12, T. 27 N., R. 23 W., at ford on county road, 4 mi northeast of Clever, Christian County.	8-21-74 2-20-75	0 0	----- -----	----- -----	----- -----	----- Pooled - no flow between pools.
173	Young Spring Branch	NE 1/4 SE 1/4 sec. 20, T. 27 N., R. 22 W., at ford on county highway, 3 mi southwest of Nixa, Christian County.	8-21-74	.1	420	18.0	-----	([3]).
174	James River (continuous-record station 07052250)	NE 1/4 NW 1/4 sec. 32, T. 27 N., R. 22 W., on left bank at Frazier Bridge, 0.2 mi. upstream from Turkey Hollow, and 2 mi southeast of Boaz, Christian County.	1972 to current year	-----	-----	-----	-----	-----
175	McCafferty Hollow	SE 1/4 SE 1/4 sec. 32, T. 27 N., R. 22 W., at ford on county highway, 4 mi southwest of Nixa, Christian County.	8-21-74	.7	460	20.5	-----	All flow was from spring at edge of channel; stream was dry upstream from spring and flow disappeared into gravel downstream.[3]
176	Finley Creek	NW 1/4 NE 1/4 sec. 27, T. 28 N., R. 17 W., at ford on county highway, 3.5 mi southwest of Seymour, Webster County.	8-30-72	0	-----	-----	-----	-----
177	Finley Creek Tributary	NW 1/4 NE 1/4 sec. 27, T. 28 N., R. 17 W., at ford on county highway, 0.1 mi south of Finley Creek and 3.5 mi southwest of Seymour, Webster County.	8-30-72	0.05	720	20.0	-----	Runoff from feed lot caused high conductance.
178	Finley Creek	SE 1/4 SE 1/4 sec. 20, T. 28 N., R. 17 W., at bridge on County Highway BB, 4 mi southwest of Seymour, Webster County.	9-12-73	0.05	-----	-----	-----	-----
179	Finley Creek	NE 1/4 SW 1/4 sec. 19, T. 28 N., R. 17 W., at ford on county highway, 5 mi southwest of Seymour, Webster County.	9-12-73	.3	340	21.0	19.0	-----
180	Finley Creek	NE 1/4 SE 1/4 sec. 24, T. 28 N., R. 18 W., at ford on county highway, 5.5 mi southwest of Seymour, Webster County.	8-30-72 9-12-73	.2 .3	----- -----	----- -----	----- -----	----- -----
181	Finley Creek	NW 1/4 SW 1/4 sec. 24, T. 28 N., R. 18 W., at ford on county highway, 6 mi southwest of Seymour, Webster County.	8-30-72 9-12-73	0 .3	----- -----	----- -----	----- -----	----- -----
182	Little Finley Creek	SE 1/4 NW 1/4 sec. 7, T. 28 N., R. 17 W., at Finley Falls on county highway, 4 mi west of Seymour, Webster County.	9-13-73	.2	360	23.0	-----	-----

See footnotes at end of Table.

Table 7 (continued).....

Map number (pl. 1)	Station name	Location	Date	Discharge (ft^3/s)	Conductance (μ mhos/cm @ 25°C)	Water temperature (°C)	Air temperature (°C)	Remarks
183	Little Finley Creek	SW 1/4 SW 1/4 sec. 13, T. 28 N., R. 18 W., at ford on county highway, 5.5 mi southwest of Seymour, Webster County.	9-12-73	1.0	-----	-----	-----	-----
184	Little Finley Creek	SE 1/4 NW 1/4 sec. 23, T. 28 N., R. 18 W., at ford on county highway, 6.5 mi southwest of Seymour, Webster County.	8-30-72 9-12-73	.4 1.5	395 370	19.5 20.0	----- 21.5	----- -----
185	Davis Branch	SW 1/4 SW 1/4 sec. 15, T. 28 N., R. 18 W., at ford on county highway, 3.5 mi southeast of Fordland, Webster County.	8-30-72 9-12-73	0 0	----- -----	----- -----	----- -----	----- There were several pools 100 yds upstream from ford on 9-12-73.
186	Davis Branch Tributary	NW 1/4 SE 1/4 sec. 16, T. 28 N., R. 18 W., at ford on county highway, 3 mi southeast of Fordland, Webster County.	8-30-72 9-12-73	0 0	----- -----	----- -----	----- -----	----- -----
187	Finley Creek	SE 1/4 NE 1/4 sec. 29, T. 28 N., R. 18 W., at ford on County Highway Z, 4.5 mi southeast of Fordland, Webster County.	8-30-72	1.3	360	23.5	-----	-----
188	Terell Branch	NW 1/4 NE 1/4 sec. 20, T. 28 N., R. 18 W., at ford on county highway, 4 mi south of Fordland, Webster County.	9-12-73	.1	-----	-----	-----	-----
189	Martins Branch	SW 1/4 NE 1/4 sec. 31, T. 28 N., R. 18 W., at ford on county highway, 5 mi south of Fordland, Christian County.	8-30-72 9-12-73	0.1 .1	----- 370	----- 23.0	----- -----	----- -----
190	Finley Creek	SE 1/4 SW 1/4 sec. 1, T. 27 N., R. 19 W., at ford on county highway, 7 mi southwest of Fordland, Christian County.	8-30-72	2.4	340	24.0	-----	-----
191	Stewart Creek	NW 1/4 sec. 12, T. 27 N., R. 19 W., at ford on county highway, 7 mi northeast of Sparta, Christian County.	9-12-73	0.05	-----	-----	-----	-----
192	Squaw Run Creek	NW 1/4 sec. 14, T. 27 N., R. 19 W., at ford on county highway, 6 mi northeast of Sparta, Christian County.	9-12-73	0	-----	-----	-----	Scattered small pools.
193	Finley Creek	SW 1/4 SW 1/4 sec. 16, T. 27 N., R. 19 W., at ford on county highway, 4 mi northeast of Sparta, Christian County.	8-30-72 9-12-73 8-21-74	2.1 2.0 9.0	320 300 320	23.0 23.0 26.0	----- 25.0 -----	----- ----- ([3]).
194	Patterson Spring	NW 1/4 NW 1/4 sec. 17, T. 27 N., R. 19 W., 300 ft south of county highway, 3.5 mi northeast of Sparta, Christian County.	8-31-72 3-5-74 8-21-74	3.8 9.22 11.0	345 305 360	14.0 13.5 14.0	----- ----- -----	----- ([1]). ([1] [3]).
195	Finley Creek	NW 1/4 SE 1/4 sec. 18, T. 27 N., R. 19 W., at bridge on county highway, 3 mi northeast of Sparta, Christian County.	8-30-72 9-12-73	7.3 14.0	300 310	24.5 22.0	----- 24.0	----- -----
196	Pedelo Creek	SE 1/4 SW 1/4 sec. 27, T. 28 N., R. 19 W., at bridge on county highway, 3.5 mi southeast of Rogersville, Webster County.	8-30-72	0	-----	-----	-----	-----
197	Pedelo Creek	NE 1/4 SE 1/4 sec. 32, T. 28 N., R. 19 W., at ford on county highway, 3 mi southeast of Rogersville, Christian County.	8-30-72 8-21-74	0 0	----- -----	----- -----	----- -----	----- One small pool downstream from ford on 8-21-74.
198	Pedelo Creek	SE 1/4 NE 1/4 sec. 6, T. 27 N., R. 19 W., at ford on County Highway U, 3 mi south of Rogersville, Christian County.	8-30-72 8-21-74	0 0	----- -----	----- -----	----- -----	----- One small pool in sight on 8-21-74.
199	Pedelo Creek	SW 1/4 SW 1/4 sec. 7, T. 27 N., R. 19 W., at mouth of creek, 6.5 mi south of Rogersville, Christian County.	8-31-72	.2	345	20.5	-----	-----
200	Finley Creek (low-flow station 07052260)	NE 1/4 NW 1/4 sec. 14, T. 27 N., R. 20 W., at bridge on county road, 2.5 mi east of Linden, Christian County.	8-29-72	6.5	340	22.0	-----	([2]).

See footnotes at end of Table.

Table 7 (continued).....

Map number (pl. 1)	Station name	Location	Date	Discharge (ft^3/s)	Conductance (μ mhos/cm @ 25°C)	Water temper- ature (°C)	Air temper- ature (°C)	Remarks
201	Finley Creek	NW 1/4 SW 1/4 sec. 18, T. 27 N., R. 20 W., at bridge on county highway, 2 mi northeast of Ozark, Christian County.	8-31-72	8.6	320	22.5	-----	-----
202	Parched Corn Hollow	SE 1/4 NW 1/4 sec. 18, T. 27 N., R. 20 W., at ford on county highway, 2.5 mi northeast of Ozark, Christian County.	8-31-72	0	-----	-----	-----	-----
			8-21-74	1.3	375	21.0	-----	(3).
203	Finley Creek (low-flow station 07052300)	SE 1/4 NE 1/4 sec. 14, T. 27 N., R. 21 W., at bridge on county highway, 1 mi north of Ozark, Christian County.	8-31-72	7.4	320	22.5	-----	-----
			9-12-73	20	310	23.0	26.0	-----
			8-21-74	36	320	24.5	-----	(2 3).
204	Finley Creek (water-quality record station 07052340)	NW 1/4 sec. 1, T. 26 N., R. 22 W., at bridge on U.S. Highway 160, 1 mi southwest of Riverdale, Christian County.	1967 to current year	-----	-----	-----	-----	-----
			9-12-73	30	340	23.0	24.5	-----
			8-21-74	48	335	24.5	-----	-----

1. See Table 6 for chemical analyses and discharge data for selected springs in the Springfield area.
2. See Table 8 for low-flow frequency data.
3. See Table 16 for chemical analyses of water from streams and springs measured during a low-flow period.
4. See Table 10 for peak-flow frequency and flood-volume data
5. See Table 9 for results of a seepage run on Lower Wilson Creek, Nov. 2, 1971.

MAGNITUDE AND FREQUENCY OF LOW FLOWS

Low-flow frequency data for streamgaging stations and springs in the Springfield area are shown in table 8. These data were computed by using procedures described by Skelton (1976). Briefly, the method involved fitting by computer the log-Pearson Type III distribution to the logarithms of the lowest mean discharges to provide low-flow frequency estimates for each station. In some instances the log-Pearson Type III distribution did not adequately fit these data, and these data were plotted against their respective recurrence intervals on log-Gumbel paper, which has a logarithmic ordinate scale and an abscissa scale based on the theory of extreme values.

The tabulation of frequency data for continuous-record stations in table 8 includes only the 7-, 14-, 30-, and 60-day periods because these data are the most commonly requested and used. However, if additional data are required for other available time periods (1, 3, 90, 120, and 183 days) arrangements can be made with the district office of the U.S. Geological Survey in Rolla, Mo., to obtain these data.

Only 7-day low-flow frequency data are shown for many of the stations in table 8. These are stations (called partial-record stations) where continuous records of stage were never collected; low-flow measurements were made at the station on different stream recessions in several different years. These measurements were related graphically to concurrent discharges at nearby continuous-record stations. Then 7-day data for two or three recurrence intervals were transferred through the relationship to obtain frequency estimates. This procedure provides reliable estimates of median values (the 2-year recurrence interval on the frequency curves) and estimates of less reliability for more extreme events. However, there is no way to mathematically evaluate the magnitude of the errors involved in the procedure.

Low-flow frequency estimates are shown in table 8 for two Wilson Creek stations. The low flows of this stream are significantly affected by urbanization, which theoretically decreases low flows because of decreased soil-moisture storage, improved drainage, and lowered groundwater levels. However, Wilson Creek's median low flows are 5 to 10 times greater than those from natural basins of comparable size in the region because of augmentation from domestic and industrial effluent. It is interesting to note that median low flows in feet^3/s per mile^2 are 0.2 - 0.3, and are comparable to values found by Miller and others (1974) for urban basins in the St. Louis, Mo., area.

As shown in table 8, there is considerable variation in the median low-flow values for unregulated streams in the

Table 8

LOW-FLOW FREQUENCY DATA FOR GAGING STATIONS, SPRINGFIELD AREA

Map number (pl.1)	Station name	Period of record (yrs.)	Drainage area (mi^2)	Period (days)	Annual low-flow, in cubic feet per second, for indicated recurrence interval, in years: 2	5	10	20	50
1	Hayes Spring near Springfield	1964-65, 1973-74	----	7	1.5	---	---	---	---
27	Pickerel Creek near Republic	1968-71	----	7	0	0	0	0	0
36	Sac River at Ash Grove	1962-65 1967, 1971	130	7	13	---	3.5	2.5	---
46	Clear Creek near Phenix	1962-64, 1967, 1970-71	----	7	5.0	---	1.0	---	---
50	J. Hart Spring near Republic	1964-65, 1970-73	----	7	2.3	---	---	---	---
61	Fulbright Spring at Springfield	1965, 1971-74	----	7	2.5	---	---	---	---
64	Williams Spring near Springfield	1965, 1972-74	----	7	0.7	---	---	---	---
74	Oak Grove Branch near Brighton	1958-73	1.30	7	0	0	0	0	0
				14	0	0	0	0	0
				30	0	0	0	0	0
				60	0	0	0	0	0
75	Cave Spring at Cave Spring	1964, 1972-74	----	7	0.1	---	---	---	---
78	Little Sac River near Morrisville	1968-73	237	7	6.0	---	2.5	---	---
98	James River near Northview	1968-70, 1972-73	----	7	1.5	---	0.1	---	---
104	Panther Creek near Northview	1972-73	----	7	0.3	---	---	---	---
125	Jones Spring at Springfield	1964-65, 1972-74	----	7	1.0	---	---	---	---
130	James River near Springfield	1956-73	246	7	11	3.1	1.0	0.3	---
				14	12	3.5	1.2	0.4	---
				30	14	4.4	1.5	0.5	---
				60	20	6.4	2.5	1.0	---
131	Winoka Spring at Springfield	1933, 1937, 1955, 1964-65, 1967	----	7	0.3	---	---	---	---
132	Sequiota Spring at Springfield	1936, 1942, 1963-64, 1967, 1972-73	----	7	1.2	---	0.6	---	---
135	Camp Cora Spring near Nixa	1955, 1963-64, 1972-74	----	7	1.1	---	0.4	---	---
139	Ward Spring near Springfield	1964, 1972-74	----	7	1.4	---	---	---	---
143	Blue Spring near Battlefield	1929, 1933, 1953, 1963-64, 1974	----	7	2.0	---	1.0	---	---
144	James River below Battlefield	1929-32	328	7	16	---	5.4	---	---
146	Wilson Creek near Springfield[1]	1933-39	19.4	7	5.2	---	---	---	---
148	Wilson Creek below Springfield[1]	1968-72	47.2	7	2.11	---	---	---	---
200	Finley Creek near Linden	1969-70, 1972	----	7	7.6	---	---	---	---
203	Finley Creek near Ozark	1943, 1946-47, 1952, 1962-67, 1973	220	7	16	---	5.2	---	---

[1] Low flows augmented by municipal and domestic effluents and outflow from sewage-treatment plant.

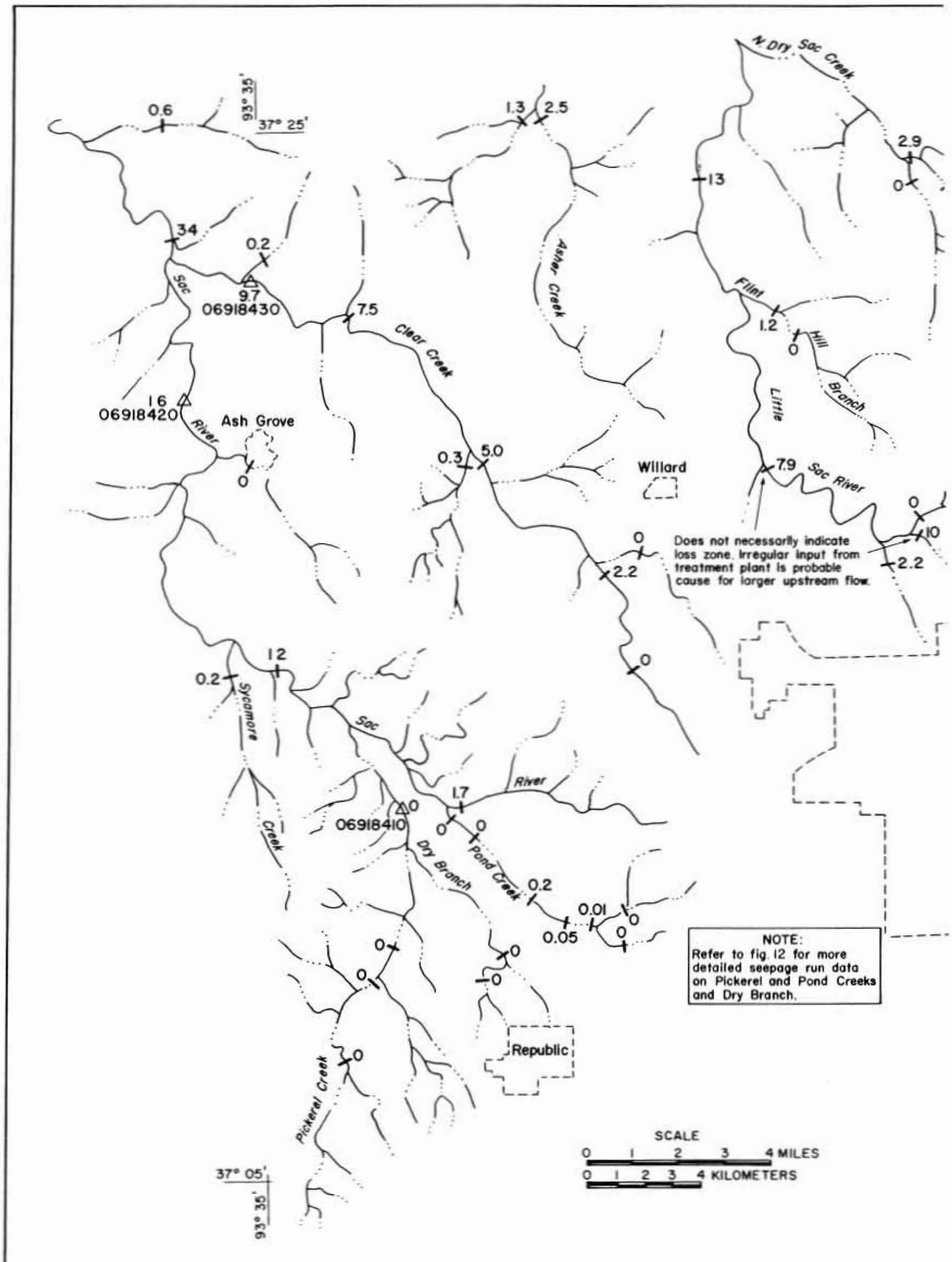


Figure 9

Results of seepage run in Sac and Pomme de Terre River basins, November 15-17, 1971.

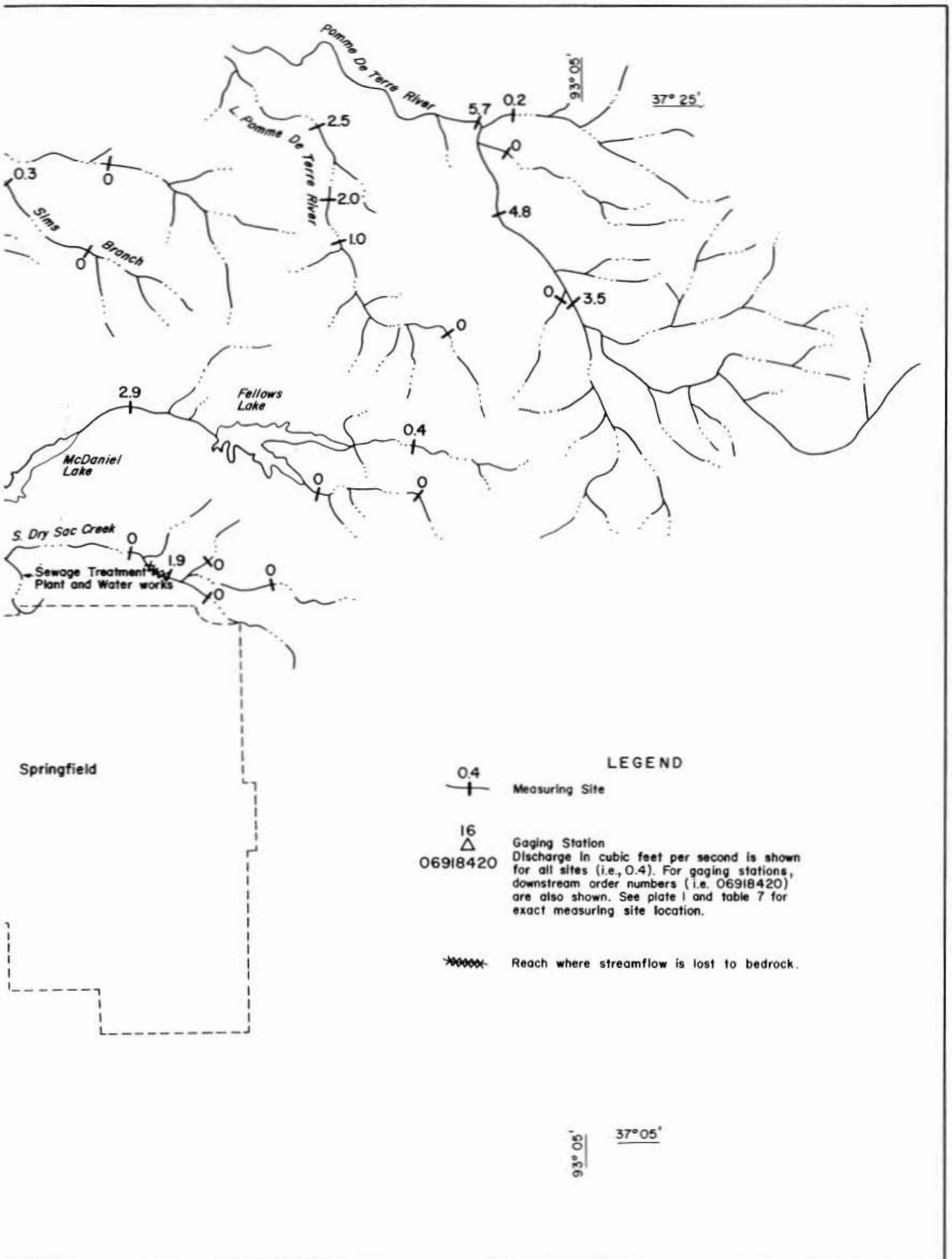


Figure 9 (continued).....

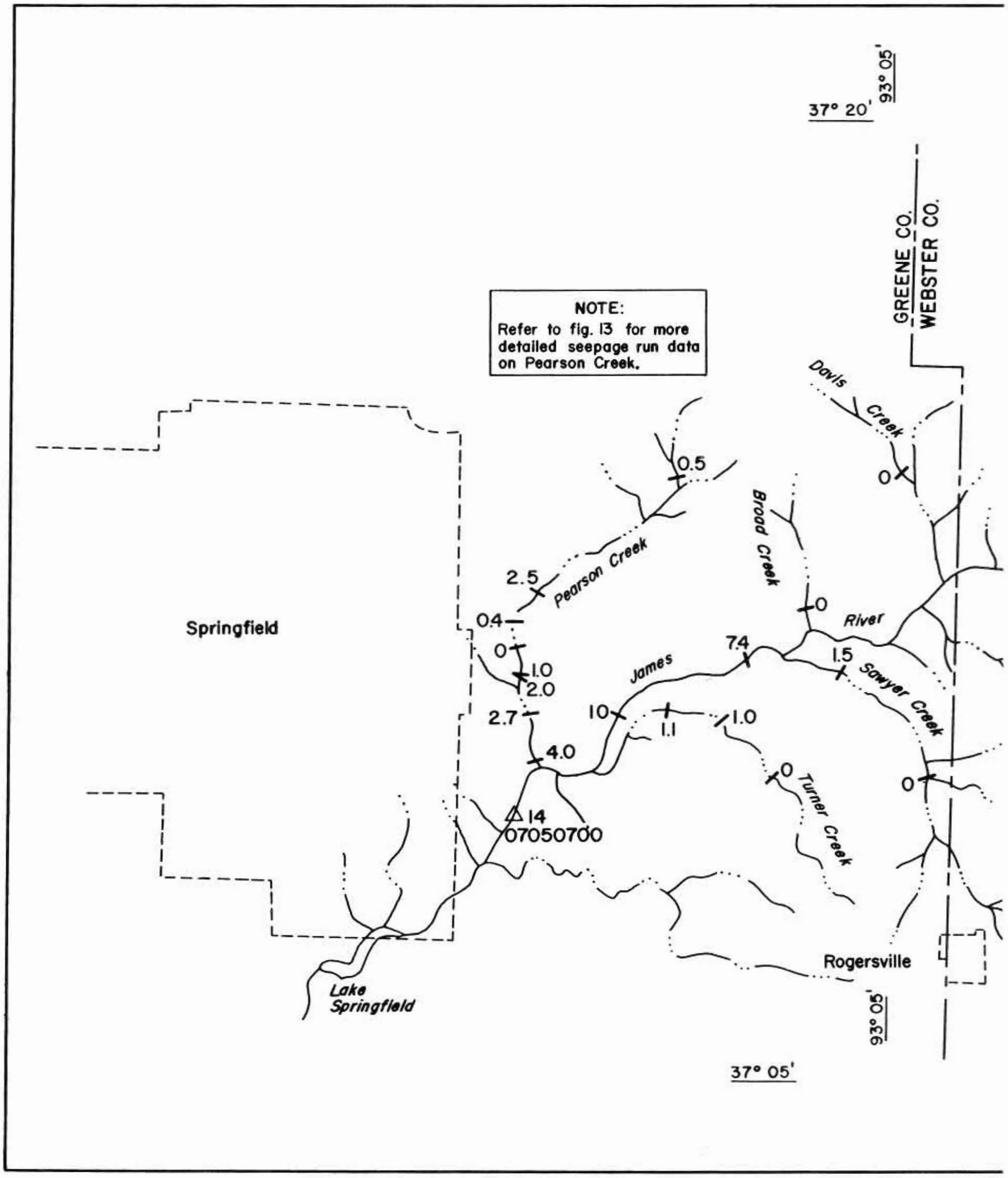


Figure 10

Results of seepage run in upper James River basin, September 10-12, 1973.

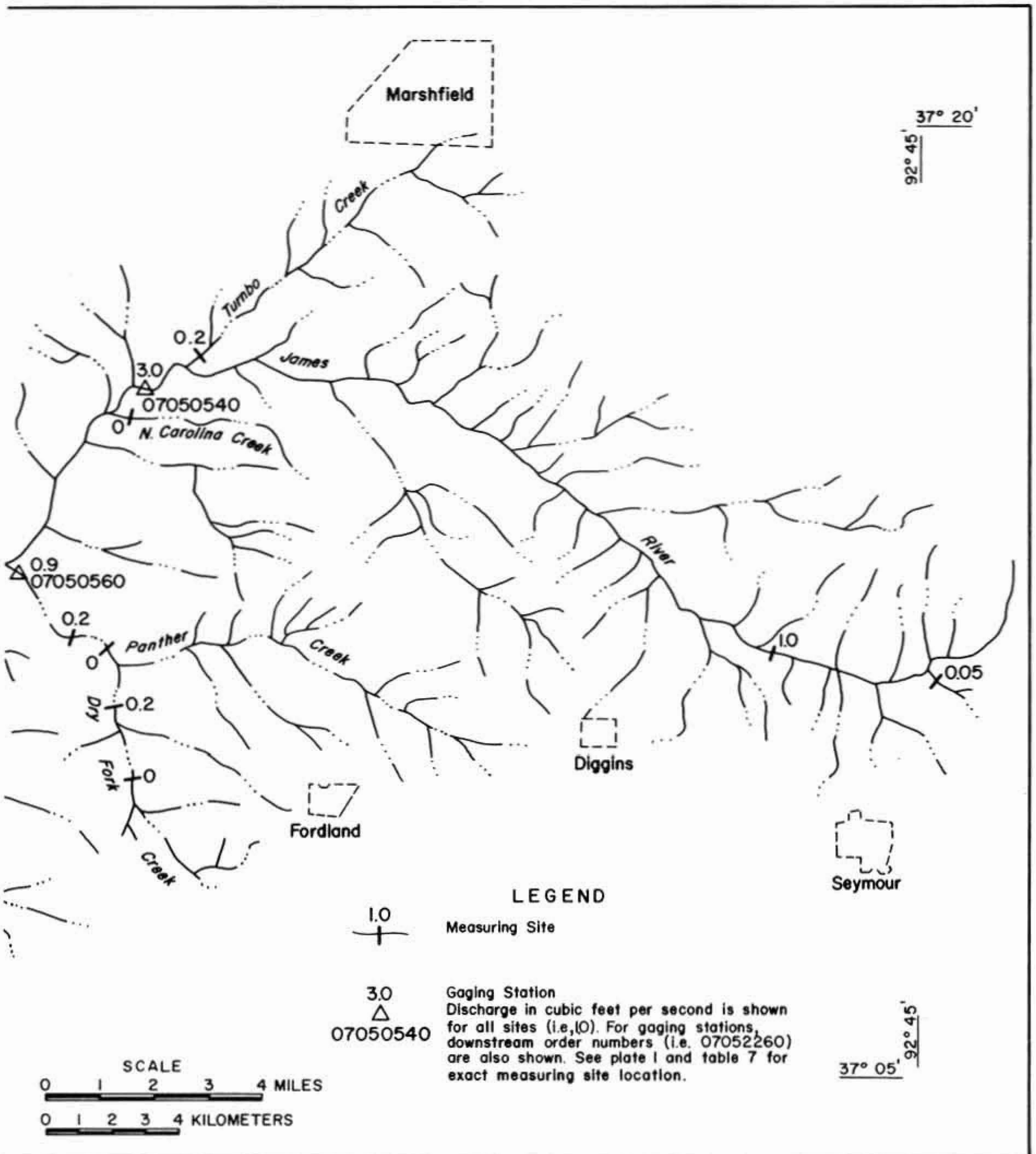


Figure 10 (continued).....

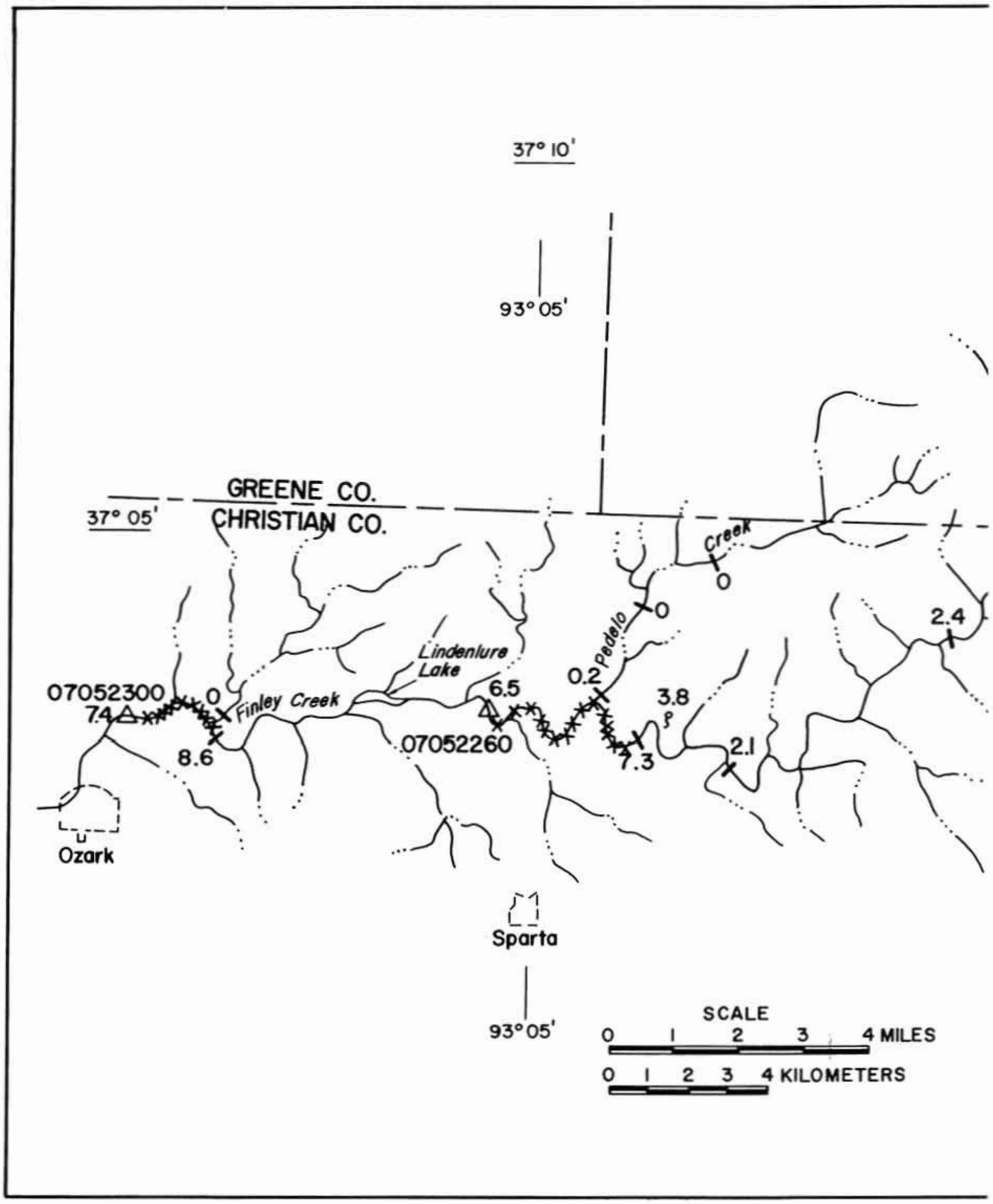


Figure 11

Results of seepage run in Finley Creek basin,
August 30-31, 1972.

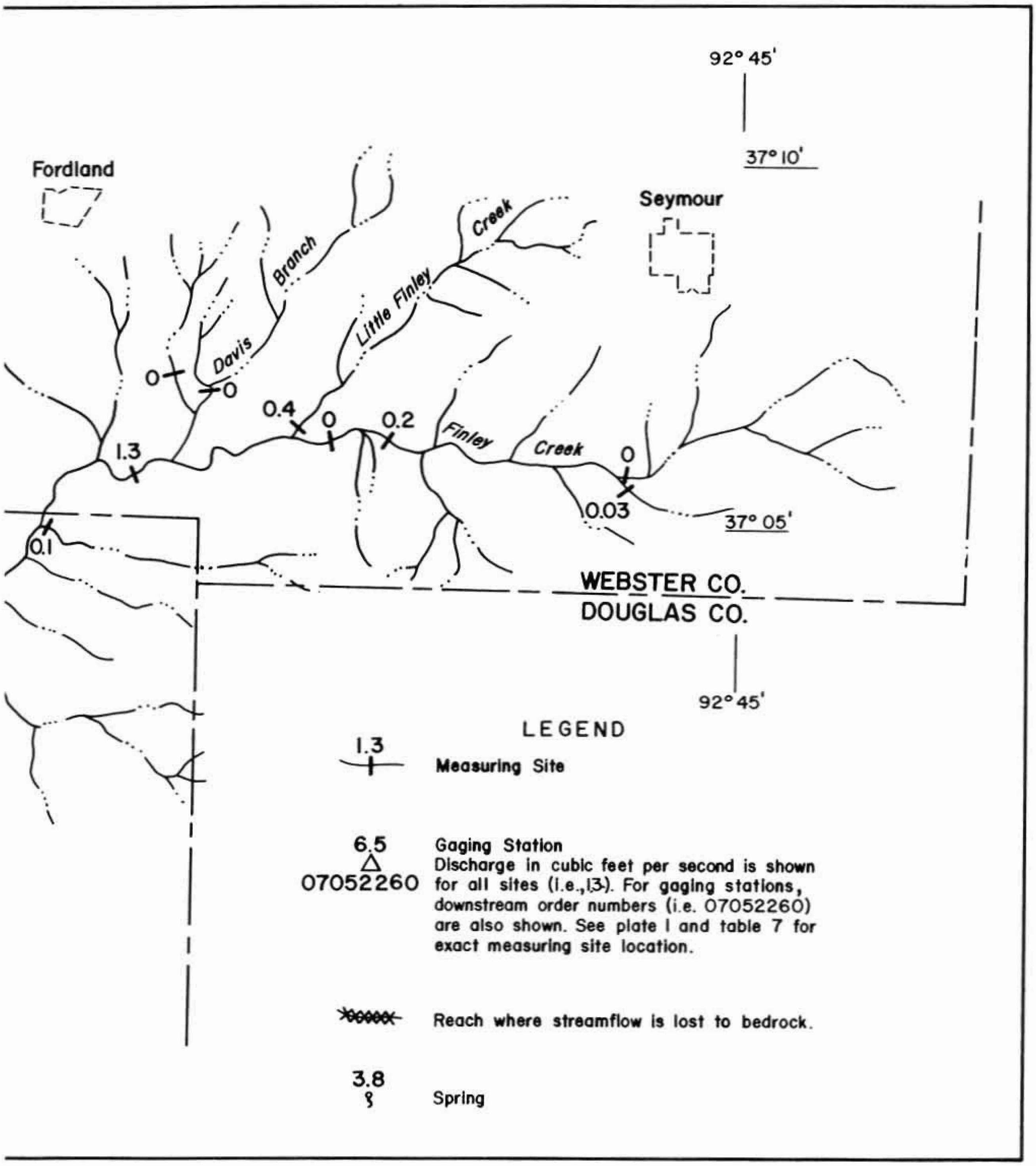
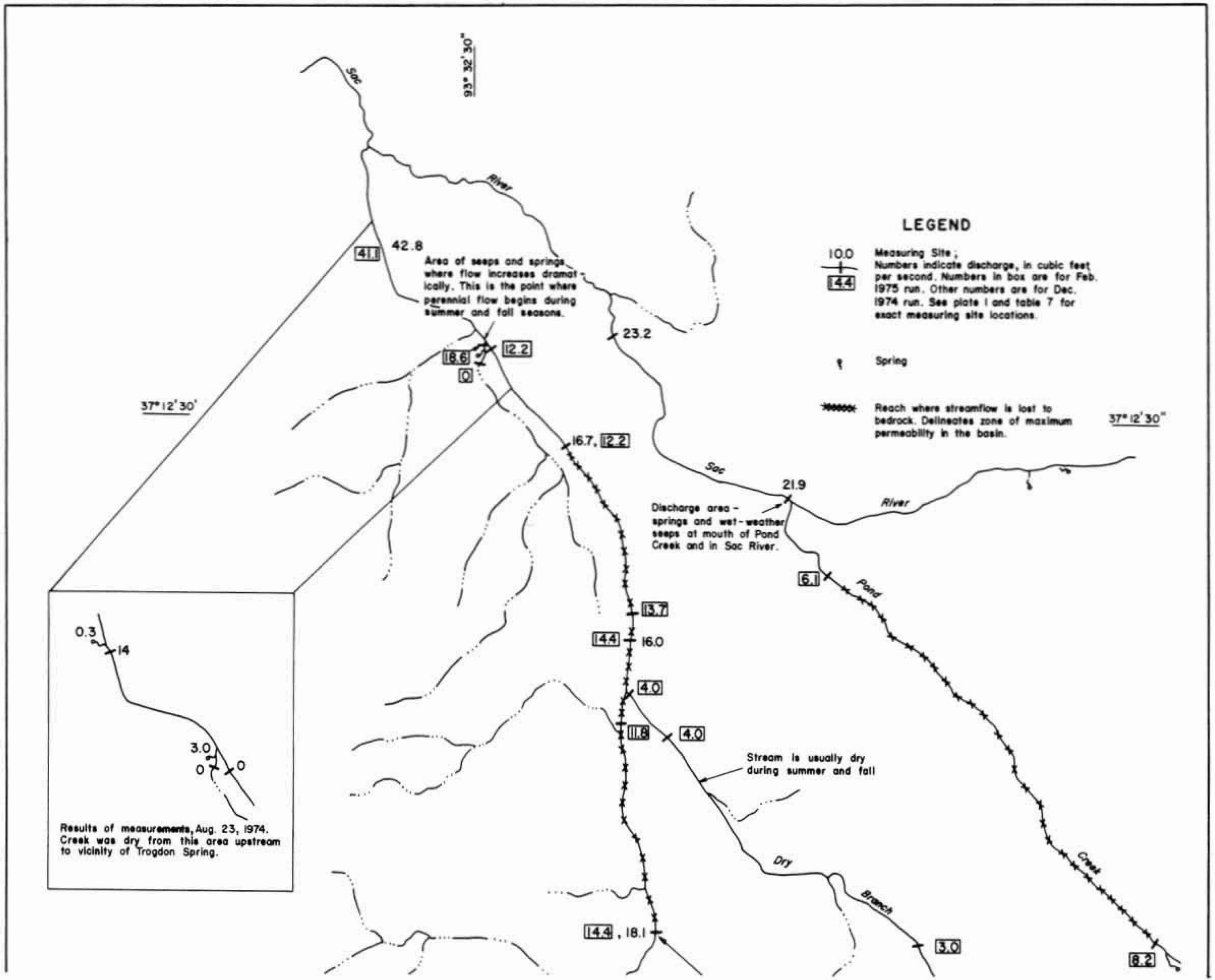


Figure 11 (continued).....


LEGEND
10.0
14.4
Measuring Site; Numbers indicate discharge, in cubic feet per second. Numbers in box are for Feb. 1975 run. Other numbers are for Dec. 1974 run. See plate I and table 7 for exact measuring site locations.
Spring
Reach where streamflow is lost to bedrock. Delineates zone of maximum permeability in the basin.
93° 32' 30"
37° 12' 30"
37° 12' 30"
Sac
River
Sac
River
Pond
Creek
Dry
Branch
42.8
41.1
Area of seeps and springs where flow increases dramatically. This is the point where perennial flow begins during summer and fall seasons.
23.2
18.6
12.2
0
16.7, 12.2
21.9
Discharge area - springs and wet-weather seeps at mouth of Pond Creek and in Sac River.
6.1
13.7
14.4
16.0
4.0
11.8
4.0
Stream is usually dry during summer and fall
14.4, 18.1
3.0
8.2
0.3
14
3.0
0
0
Results of measurements, Aug. 23, 1974. Creek was dry from this area upstream to vicinity of Trogdon Spring.

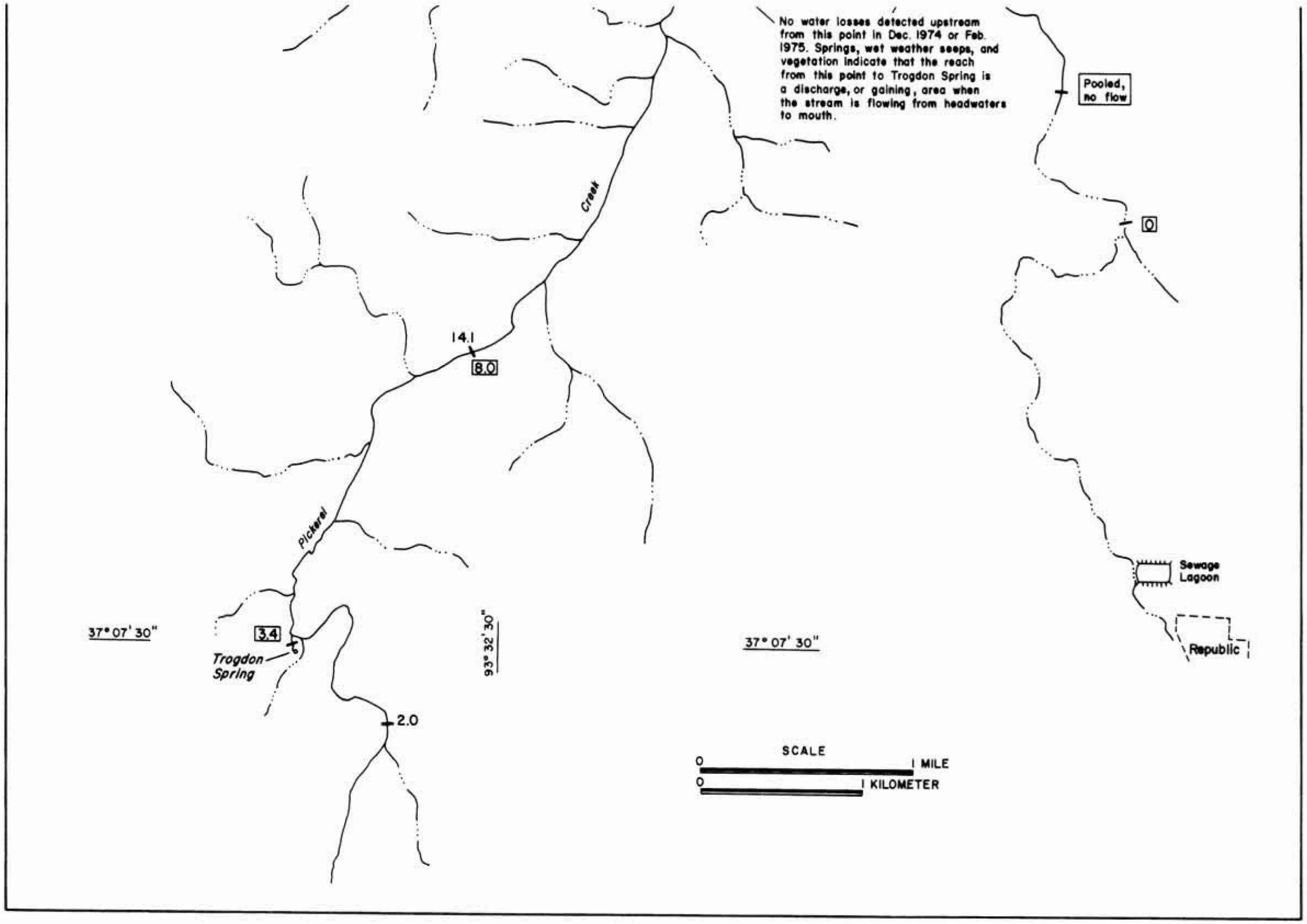


Figure 12

Results of seepage runs in Pickerel Creek basin, December 10-11, 1974, and February 18-19, 1975.

area. An inspection of the geologic map (pl. 2) shows that these variations are closely related to the bedrock geology. For example, streams draining the Jefferson City Dolomite (upper Finley Creek, upper James River, and a major part of the Little Sac River) have 7-day Q_2 discharges of 0 to 0.04 foot^3/s per mile^2. Those streams draining the Mississippian limestone, on the other hand, generally have 7-day Q_2 discharges of 0.05 to 0.10 foot^3/s per mile^2. The seepage-run data in the following section will give a more precise evaluation of low-flow patterns and should be used to locate gaining and losing stream reaches.

SEEPAGE-RUN INFORMATION

Seepage-run information is an excellent indicator of the magnitude and distribution of low flows within a basin. When used in conjunction with the low-flow frequency data presented in table 8, the magnitude and frequency of low flows at many points within a basin can be estimated. These data are invaluable in locating municipal treatment plants, municipal and private sewage lagoons, and industrial plants so as to insure minimum risk of aquifer contamination. These data are also very useful to individuals who are interested in the location and design of surface-water impoundments on small tributary streams, and who need to know which basins and stream reaches are amenable to the use of generalized equations for mean flows and peak discharges.

In the Springfield area, seepage-run data were collected systematically during the study (tbl. 7 and figs. 9 to 14), with special effort being made during periods of minimum streamflow. Data were also collected in the winter and spring during periods when storm runoff was negligible from selected stream reaches where previous seepage runs indicated zones of appreciable streamflow losses (see figs. 12-14). These limited seepage runs supply valuable information about areas of excessive water loss to underground solution cavities and indicate reaches where disposal of any type of effluent into the stream will be likely to contaminate shallow groundwater supplies.

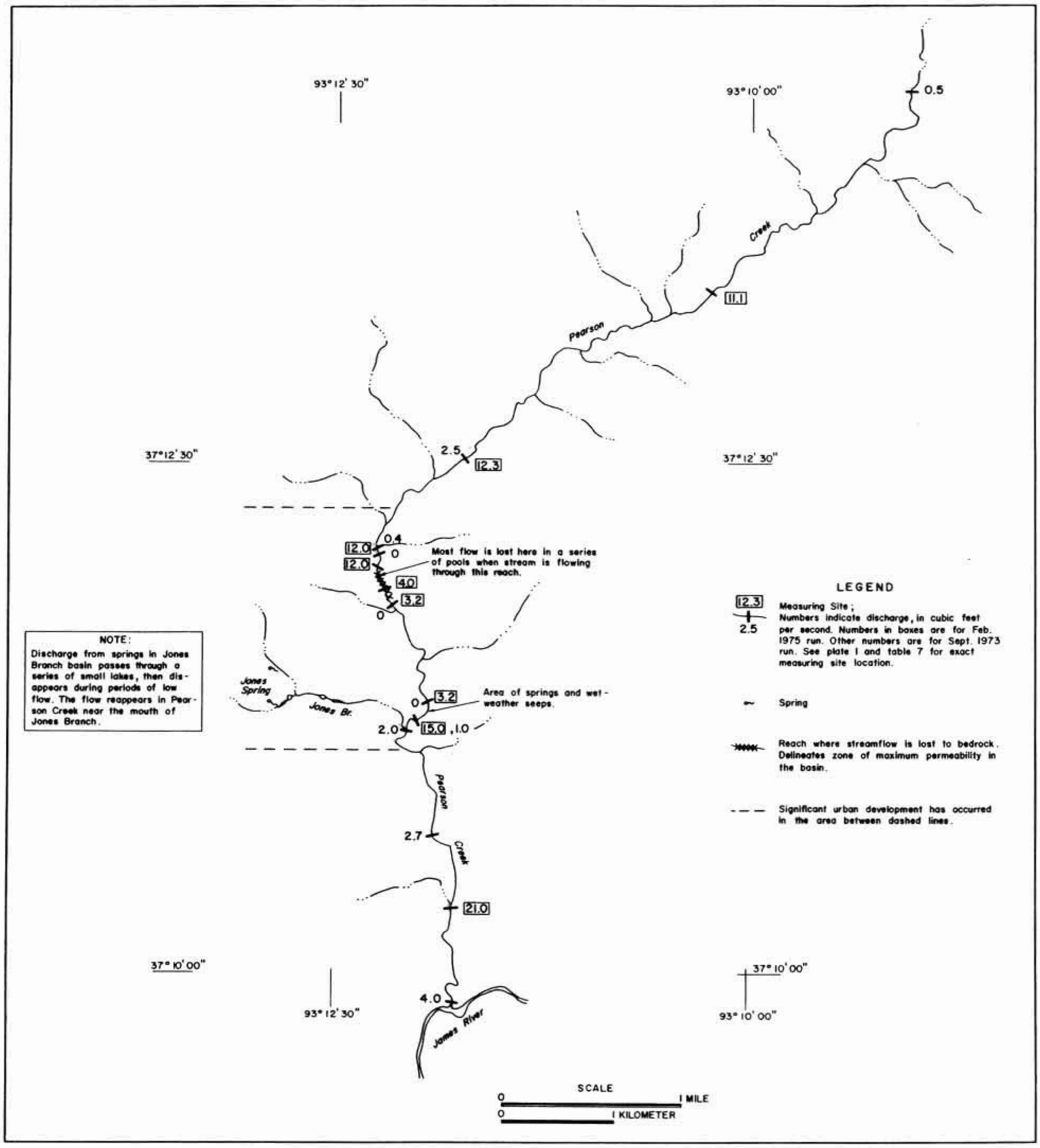


Figure 13

Results of seepage runs in Pearson Creek basin, September 10, 1973, and February 20, 1975.

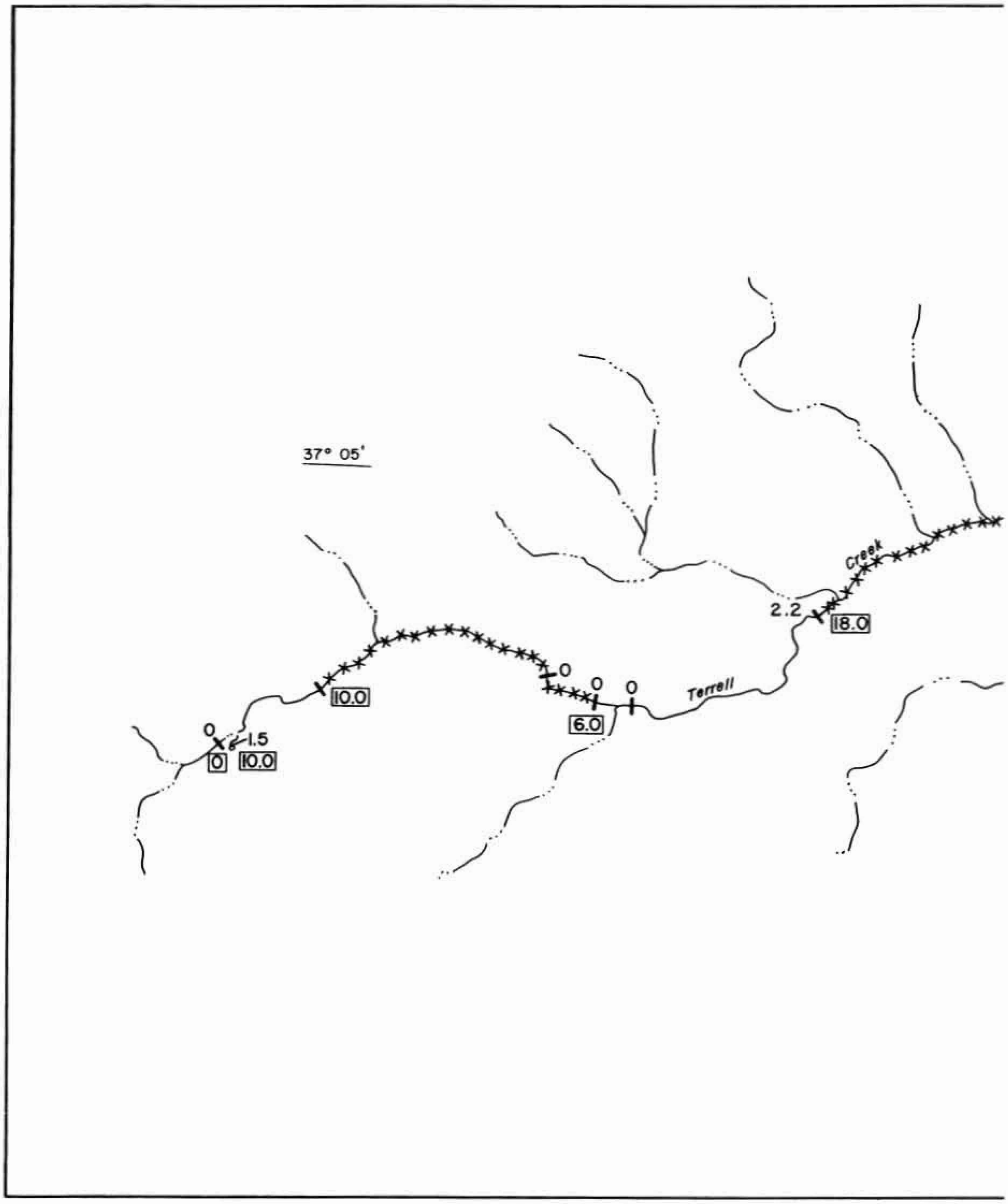


Figure 14
Results of seepage runs in Terrell Creek basin,
September 13, 1973, and April 9, 1975.

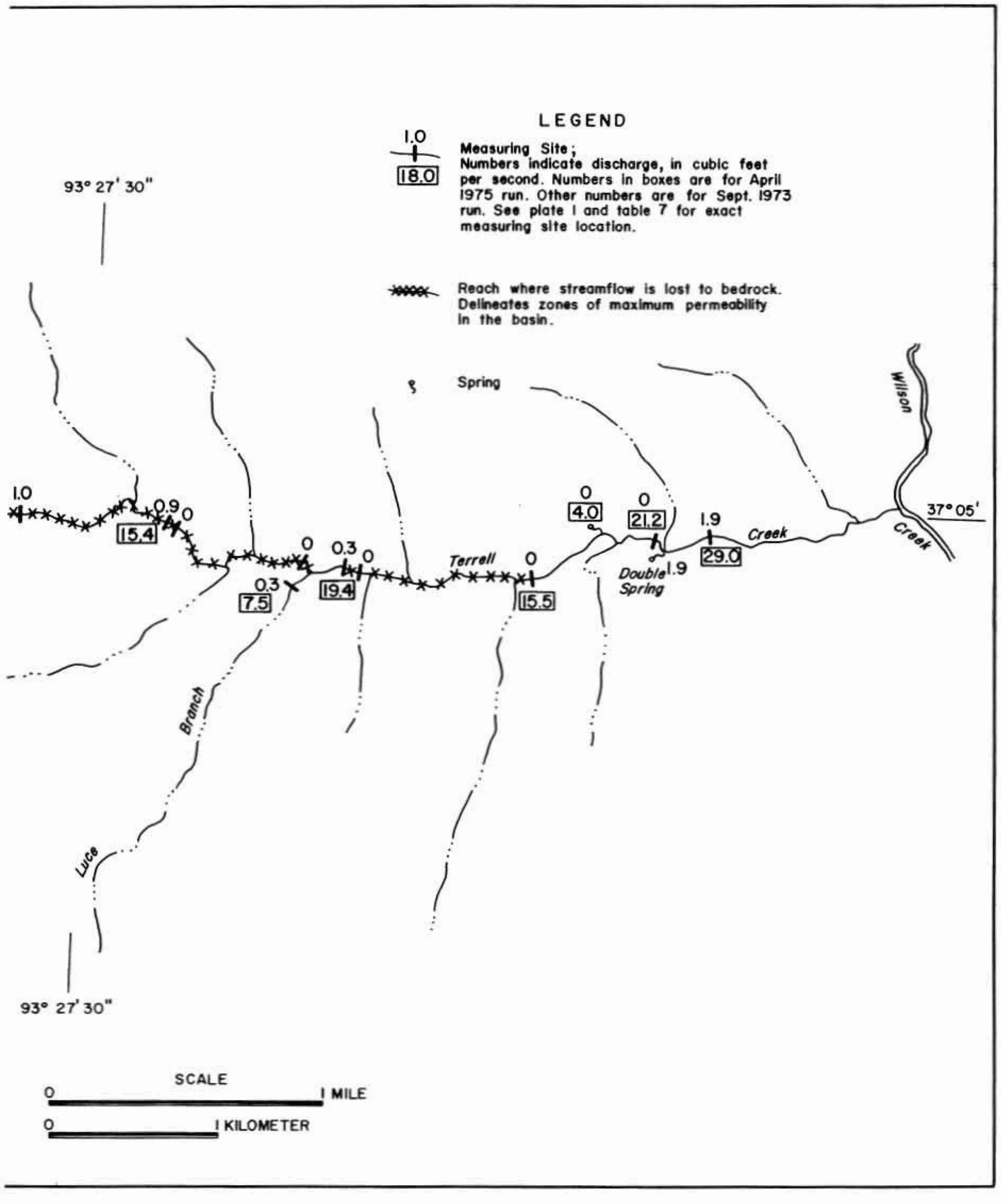


Figure 14 (continued).....

For comparative purposes, the results of low-flow measurements made on the James River during the most extreme drought on record in the Springfield area (1954) have been included in table 7. Also note that the low-flow frequency of the seepage runs is shown at the bottom of each map (figs. 9 to 14). These data can be used to estimate the magnitude and frequency of low flows at many points in the basins.

The following short discussions of basin seepage runs are included to clarify the data shown in figures 12 to 14 and to present the authors' interpretation of the data collected in selected basins. These are the basins where significant water losses or gains have been detected.

Pickerel Creek Basin

Pickerel Creek basin, located in a rural setting about 10 miles west of Springfield, ceases to flow throughout most of its length during periods of little or no precipitation in the summer and fall. During winter and spring, however, flow is often continuous from its headwaters to its mouth. A major question facing water resource investigators is, "Is Pickerel Creek a losing stream throughout most of its length or only in certain segments of the dry reach?" The answer to the question could have an important bearing on future basin development.

Figure 12 shows the results of seepage-run measurements in August and December of 1974 and February 1975. In contrast to the August run when there was no flow in much of the basin, the December and February runs were made during periods when the stream was flowing in all reaches. These runs indicate that during very high baseflow periods, when the soil is saturated and evapotranspiration rates are very low, there is a reach of about 2.5 miles in the lower middle portion of the basin where streamflow is lost to bedrock. Streamflow losses under these hydrologic conditions could only indicate surface-water movement toward the shallow groundwater aquifer.

It is possible, but not probable, that surface flow is lost to the shallow aquifer in the upper parts of the basin during dry weather. More than likely, however, the small headwater flows from Trogdon Spring (pl. 1, map no. 14) disappear into the gravel fill and are dissipated by evapotranspiration.

Pearson Creek Basin

The hydrology of Pearson Creek, a tributary of the James River near the eastern city limits of Springfield, was studied carefully because (1) it is an interrupted stream for a considerable time during most years, (2) structural features in the basin are complex and their relationship to surface and ground water has never been determined, and, (3) the basin, though primarily undeveloped except for subdivisions in its middle reaches, is a prime candidate for complete urbanization as the city expands to the east.

Major structural features are shown on the geologic map (pl. 2). The Pearson Creek fault system and the Danforth graben apparently have little effect on surface-flow patterns. Seepage runs show that the flow increases rather uniformly in the upper and lower reaches of the stream where these structures are located.

During periods of low streamflow in the summer and fall, Pearson Creek flow is interrupted. As shown in figure 13, the interrupted reach coincides with the area of initial urban development in the basin.

Great care should be taken in planning water systems and waste-disposal facilities for the interrupted reach as urbanization continues and intensifies. There is little doubt that shallow groundwater supplies in the area could be extensively affected by unregulated development and growth. Hydraulic connection between shallow and deep groundwater sources emphasizes the importance of considering the potential intersection between surface and ground water in this area very carefully during future development.

Terrell Creek Basin

Terrell Creek is representative of a number of Ozarks streams that have alternate gaining and losing reaches throughout their entire lengths. Seepage runs in September 1973 and April 1975 were used to define the alternate gaining and losing characteristics of the stream.

Although the September seepage run was valuable in showing the general flow characteristics of the basin, the most useful run occurred during a time of stable but saturated conditions in April when the stream was flowing in all reaches. Note the comparison of results from the two seepage runs in figure 14. Reaches where loss to bedrock occurs are much better defined by the April data because measured losses cannot be attributed to movement through the gravel (it was saturated) or to evapotranspiration (vegetation was still relatively dormant).

Wilson Creek Basin

The urbanized Wilson Creek basin has been the object of intensive hydrologic studies in the past for two primary reasons: (1) occasional fish kills, associated with storm runoff, in Wilson Creek and the James River downstream from the mouth of Wilson Creek, and (2) odorous and unsightly conditions in the vicinity of Wilson Creek Battlefield National Park. These two problems are caused by extensive urbanization and related storm runoff in the headwater areas and the fact that Wilson Creek is used to transport sewage effluent away from the main sewage-treatment plant in Springfield's waste-disposal system.

Because past studies have resulted in extensive analyses of hydrologic problems in the basin and because a study of urbanization effects is beyond the scope of this report, very little additional effort was expended in the basin during this study. Seepage runs were obtained on Terrell Creek, an interrupted-type stream that is tributary to lower Wilson Creek (see fig. 14) and the lower reaches of Wilson Creek. Table 9 is a tabulation of the data collected in lower Wilson Creek during this study. The data indicate that Wilson Creek downstream from Rader Spring is not a losing stream, at least during high base flow conditions.

For information obtained during past studies in the Wilson Creek Basin, refer to reports by the Federal Water Pollution Control Administration, now known as the Environmental Protection Agency (1969), and Harvey and Skelton (1969). Current data from quality-of-water monitors located in the basin are published annually by the U.S. Geological Survey, Rolla, Mo., in "Water Resources Data for Missouri, Parts 1 and 2" (see section of this report entitled "Effects of Urban Runoff on Water Quality" for analysis of data collected at monitored sites).

MAGNITUDE AND FREQUENCY OF FLOOD PEAKS AND VOLUMES

Increasing urbanization and encroachment of domestic and industrial structures on the floodplains of streams pose special flood problems to planners, consultants, and government agencies in the Springfield area. This increasing activity in the area brings with it the threat of more frequent severe floods and greater flood damages as impervious surfaces cover greater percentages of drainage basins.

Table 9

RESULTS OF SEEPAGE RUN ON LOWER WILSON CREEK
NOVEMBER 2, 1971

Map number (pl.1)	Station name and location (in downstream order)	Time when discharge was observed	Discharge (ft. ³/S)	Distance between sites (mi.)	Estimated streamflow travel time (hrs.)
148	WILSON CREEK SW 1/4 NE 1/4 sec. 7, T.28 N., R.22 W., 1,700 ft downstream from South Creek. (continuous-record gaging station 07052150).	0945-1100 1130 1200-1230 1300-1745	20 21 23 24	1.9	3.5
150	WILSON CREEK SW 1/4 sec. 18, T.28 N., R.22 W., at bridge on county road, 3,000 ft downstream from Rader Spring.	1040 1215 1415 1540	27.8 27.6 30.5 33.5	1.3	2.4
151	WILSON CREEK NW 1/4 SW 1/4 sec. 24, T.28 N., R.23 W., at bridge on county road, 2,000 ft upstream from McElhaney Branch. (continuous-record gaging station 07052160).	1140 1255 1500 1620	28.4 29.1 32.2 32.9	1.4	2.6
152	WILSON CREEK NW 1/4 SW 1/4 sec. 25, T.28 N., R.23 W., at bridge on county road, 1,500 ft upstream from Shuyler Creek.	1110 1420 1610 1700	27.1 28.2 29.6 33.6	1.8	3.3
167	WILSON CREEK On line between secs. 1 and 36, T.27 and 28 N., R.23 W., at Manley Ford, 1,500 ft downstream from Terrell Creek.	1245 1505 1650	30.5 26.5 27.9		

Note:
1. Terrell Creek flow of 1.1 cubic feet per second (ft. ³/S) is not included in discharge figures for Wilson Creek at Manley Ford. This allows direct comparison of mainstream reaches.
2. McElhaney Branch and Shuyler Creek were dry.
3. Use estimated travel time between sites to account for a gradual increase in flow from the sewage-treatment plant during the day and compare similar flow conditions at the sites. For example, the first discharge at site 150 is comparable to the second discharge at site 151.
4. Flow at Manley Ford was slightly less than at site 151. The small differences (about 1 1/2 percent) can be attributed to evaporation loss and measurement accuracy.

The purpose of this section is to present flood information from gaging stations in the area and outline methods for estimating the magnitude and frequency of flooding at ungaged sites. These data and methods can be especially helpful in insuring the proper planning and design of water facilities in the area.

It should be pointed out that a very useful source of historical flood data and frequency information are the U. S. Army Corps of Engineers' floodplain information reports on Wilson Creek and tributaries, Part 1, and James River and tributaries, Part II. These reports can be obtained from the Director of Planning for Springfield, Mo., or from the Little Rock, Ark., Office of the U.S. Army Corps of Engineers.

Gaged Sites in Rural and Urban Basins

Peak-flow frequency and flood-volume data for the gaging stations shown in table 10 were determined for the most part by computer, mathematically fitting a log-Pearson Type III distribution to the logarithms of the annual peak and highest mean discharge data, as described by the U. S. Water Resources Council (1967). A graphical frequency curve, plotted on extreme-value graph paper, was used for those stations for which the log-Pearson Type III curve was not a reasonable fit to the data.

For some gaging stations in the area, streamflow data were scant or were affected to such a variable extent by urbanization that frequency analysis was not attempted. The basic peak-flow data for these stations are presented in table 11.

Flooding from heavy rains could occur in any month, but has been most frequent during the 3-month period from March to May. Gaging-station data show that flooding in the Srpingfield area is much more likely to occur in May than in any other month. During the 20-year period from 1956 to 1975, approximately two and a half times more floods occurred in May than in any other month. On the other hand, no flooding of any consequence occurred in August during the period of record.

Ungaged Sites in Rural Basins

There are many basins in the area in which flood-frequency relationships have not been affected appreciably by the activities of man. In these areas, it is recommended that flood-peak and volume equations developed by Hauth (1974) and Skelton (1973), respectively, be used to compute the peak discharges and volumes of floods with selected recurrence intervals. Although the possibility of redefining flood-frequency relationships for southwestern Missouri was considered, a plot of the equation residuals (observed station values divided by computed values) indicated a random pattern for the southwestern Missouri region with the ratios ranging from 0.56 to 1.67 for flood peaks and

Table 10

PEAK-FLOW FREQUENCY AND FLOOD-VOLUME DATA FOR GAGING STATIONS, SPRINGFIELD AREA

Map number (pl.1)	Station name	Period of record (yrs.)	Drainage area (mi^2)	Slope (ft/mi)	PEAK-FLOW DATA: Magnitude of peak, in cubic feet per second, for indicated recurrence interval, in years.						Recurrence Interval (yrs.)	FLOOD-VOLUME DATA: Flood volume, in acre-feet, for indicated duration, in days.							
					2	5	10	25	50	100		0.25	0.50	0.75	1	3	7	15	30
16	Pickerel Cr. Tributary near Republic	1957-74	0.57	68.8	105	195	255	330	385	435	---	----	----	----	------	------	-------	-------	-------
74	Oak Grove Branch near Brighton	1957-74	1.30	94.2	180	390	565	820	1,020	1,200	2	58	72	80	86	110	126	150	180
											10	135	162	180	200	250	308	360	420
											25	172	185	218	250	336	420	540	600
79	Franca Branch near Brighton	1955-74	0.59	109	119	265	405	660	915	1,230	---	----	----	----	------	------	-------	-------	-------
130	James River near Springfield	1956-74	246	6.50	9,910	17,500	22,800	29,500	35,000	42,000	2	----	----	----	11,200	18,600	23,700	30,900	40,200
											10	----	----	----	22,600	42,200	57,400	73,800	94,200
											25	----	----	----	29,000	58,800	78,900	102,000	131,000
											50	----	----	----	31,700	70,000	95,800	124,000	160,000
											100	----	----	----	37,600	80,200	115,000	151,000	195,000
136	Maple Grove Branch near Ozark	1957-74	0.64	59.5	130	300	465	740	1,000	1,320	---	----	----	----	------	------	-------	-------	-------

Table 11

MISCELLANEOUS FLOOD DATA

WHITE RIVER BASIN

Map number 144 (pl. 1, table 7)
07051500. James River below Battlefield, Mo.
(Published as "near Battlefield" prior to June 1929)

Location.--Lat 37°05'30", long 93°21'25", in NE¼ sec.32, T.28N., R.22 W., at Blue Spring Highway bridge, 1.6 mi southwest of Battlefield and 3 mi upstream from Wilson Creek, Christian County.

Drainage area.--328 mi^2; 303 mi^2 prior to May 13, 1929.

Period of record.--1926-32.

Slope.--6.33 ft/mi.

Gage.--Nonrecording. Feb. 17, 1926, to May 13, 1929, at site 3 mi upstream at datum about 10 ft higher. May 13, 1929, to Jan. 7, 1932, at last used site and datum. Altitude of gage at last used site is 1,090 ft, from topographic map.

Average discharge.--416 ft^3/s.

Peak stages and discharges

Date	Gage height (ft)	Discharge (ft^3/s)
Sept. 30, 1926	6.30	1,920
Apr. 15, 1927	15.00	14,600
June 28, 1928	16.10	16,800
Apr. 9, 1929	11.20	8,010
Jan. 14, 1930	9.82	4,630
Aug. 6, 1931	10.50	5,350

Table 11 (continued).....

WHITE RIVER BASIN

Map number 146 (pl. 1, table 7)
07052000. Wilson Creek near Springfield, Mo.

Location.--Lat 37°11'35", long 93°20'20", in NW¼SE¼ sec.28, T.29 N., R.22 W., three-quarters of a mile downstream from Jordan Creek and 2 miles southwest of Springfield, Greene County.

Drainage area.--19.4 mi^2. Slope.--23.3 ft/mi.

Period of record.--1933-39.

Gage.--Recording. Datum of gage is 1,196.16 ft above mean sea level, datum of 1929.

Average discharge.--21 ft^3/s.

Remarks.--Flow affected by urbanization of headwater areas.

Peak stages and discharges

Date	Gage height (ft)	Discharge (ft^3/s)
June 27, 1932	7.62	2,440
July 8, 1933	5.07	922
June 15, 1934	3.82	424
June 16, 1935	5.57	1,080
Sept. 28, 1936	3.77	398
June 14, 1937	6.87	1,880
June 16, 1938	5.35	980

Table 11 (continued).....

WHITE RIVER BASIN

Map number 148 (pl. 1, table 7)
07052150. Wilson Creek below Springfield, Mo.

Location.--Lat 37°08'49", long 93°22'26", in SW¼NE¼ sec.7, T.28 N., R.22 W., 1,700 ft downstream from South Creek, and 2,500 ft downstream from Southwest Sewage Treatment Plant of Springfield. Prior to Oct. 14, 1970, at site 1,500 ft upstream.

Drainage area.--47.2 mi^2. Slope.--17 ft/mi.

Period of record.--April 1967 to September 1972 (discontinued).

Gage.--Water-stage recorder. Datum of gage is 1,126.10 ft above mean sea level. Prior to Oct. 14, 1970, at site 1,500 ft upstream at datum 2.86 ft higher.

Average discharge.--5 years, 38.4 ft^3/s.

Remarks.--Streamflow partly regulated and affected by sewage effluent, urban runoff, and natural upstream diversions of flow through underground solution channels.

Peak stages and discharges

Date	Gage height (ft)	Discharge (ft^3/s)
Dec. 21, 1967	9.05	3,700
Jan. 29, 1969	6.82	1,520
Apr. 30, 1970	7.08	1,650
Sept. 5, 1971	5.18	960
Sept. 15, 1972	5.83	1,180

0.93 to 1.29 for flood volumes. Thus it was not considered worthwhile to attempt to improve the estimating equations already available.

The peak-flow equations presented in table 12 can be solved by utilizing two drainage basin characteristics: (a) drainage area (A), which is the contributing drainage in mile^2 upstream from any site along a river channel, and (b) average main-channel slope (S), which is defined as the average basin slope, in feet/mile, between points 10 and 85 percent of the total main-stem distance upstream from the site. An example of the steps needed to solve the equations is as follow:

Assume that the magnitude of a flood peak with recurrence interval of 100 years is desired for a site in a small rural basin in eastern Greene County. The following steps are necessary:

a. Determine the drainage area in mile^2 by planimetering along the drainage divide for the basin upstream from the site. Assume that the drainage area is 0.5 mile^2.

Table 12

SUMMARY OF PEAK-FLOW EQUATIONS

Frequency of flood (yrs)	Magnitude of flood (ft^3/s)	Standard error of estimate (percent)
2	$53.5A^{0.851A^{-0.02}}S^{0.356}$	38.6
5	$64.0A^{0.886A^{-0.02}}S^{0.450}$	34.7
10	$67.6A^{0.905A^{-0.02}}S^{0.500}$	34.5
25	$73.7A^{0.924A^{-0.02}}S^{0.542}$	35.0
50	$79.8A^{0.926A^{-0.02}}S^{0.560}$	33.3
100	$85.1A^{0.934A^{-0.02}}S^{0.576}$	33.3

b. Compute the average main-channel slope in foot/mile by determining the difference in elevation and distance between sites 10 and 85 percent of the main-channel distance upstream from the site. Assume that the distance, stepped off by using dividers set at 0.1 mile, is 0.3 mile and that the difference in elevation between the two points is 21 feet. The average main-channel slope is $\frac{21 \text{ ft}}{0.3 \text{ mi}}$ = 70 feet/mile.

c. From table 12, the equation for the 100-year flood is:

F_{100}=85.1 $A^{0.934A^{-0.02}}S^{0.576}$. Substituting the values of 0.5 mile^2 and 70 feet/mile in the equation and solving it, a value of 511 feet^3/s is obtained for the 100-year flood. For convenience in solving the equations, a graphical presentation of the 2-, 50-, and 100-year floods are shown in figures 15, 16, and 17. By using figure 17, and entering the graph with appropriate values of drainage area and slope, a value of 500 feet^3/s is obtained.

The flood-volume equations, presented in table 13, can be solved by utilizing one or more of the following drainage basin characteristics:

a. Drainage area (A), which is the contributing drainage in square miles upstream from any site along a river channel.

b. Mean annual runoff (R), in inches. For the Springfield area, a value of 12 inches can be used.

c. Soils index (S_i), in inches, which have been determined for sub-basins within the state by the Soil Conservation Service (written commun., 1970). In the Springfield area a value of 3.8 can be used for streams in the James River basin, 2.8 for streams in the Sac River basin, and 3.3 for streams in the Pomme de Terre River basin.

d. Mean basin elevation (E), in feet above mean sea level. These data can be obtained from 1:62,500 and 1:24,000 scale U.S. Geological Survey topographic maps for small drainage basins and 1:250,000 scale U.S. Geological Survey maps for large basins. The elevation can be computed by laying a grid over the map, determining the elevation at each grid intersection and averaging those elevations. The grid spacing should provide about 20 intersections within the basin boundary.

The flood-volume equations of table 13 are of the same general form as the flood-peak equations and can be solved as described in the preceding example. Note that the flood-volume characteristics are shown symbolically in the table. For example, $V_{0.25,\ 2}$ represents a 6-hour flood volume with recurrence interval of 2 years; $V_{7,\ 25}$ represents a 7-day flood volume with

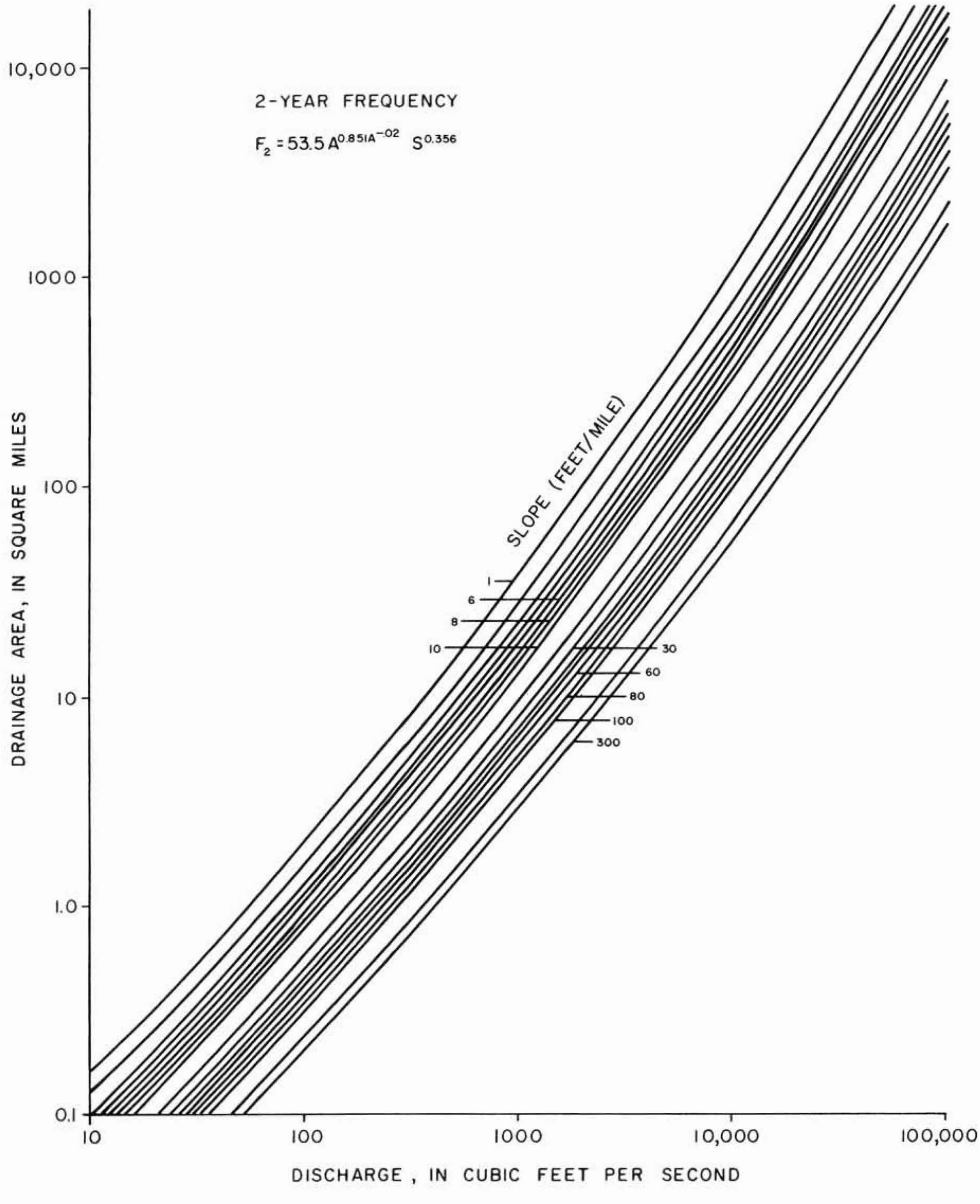


Figure 15

Graphical solution of the 2-year equation.

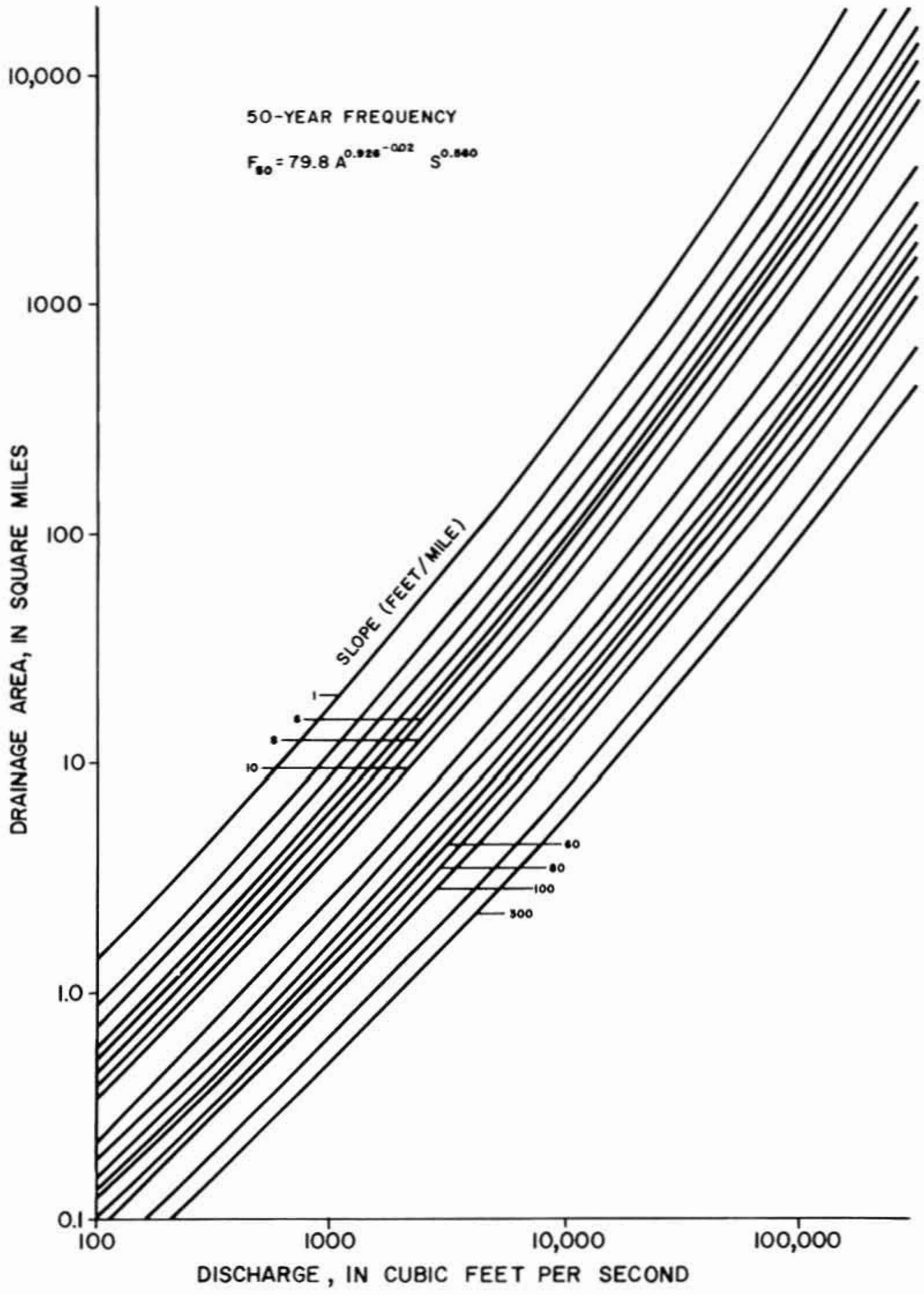


Figure 16

Graphical solution of the 50-year equation.

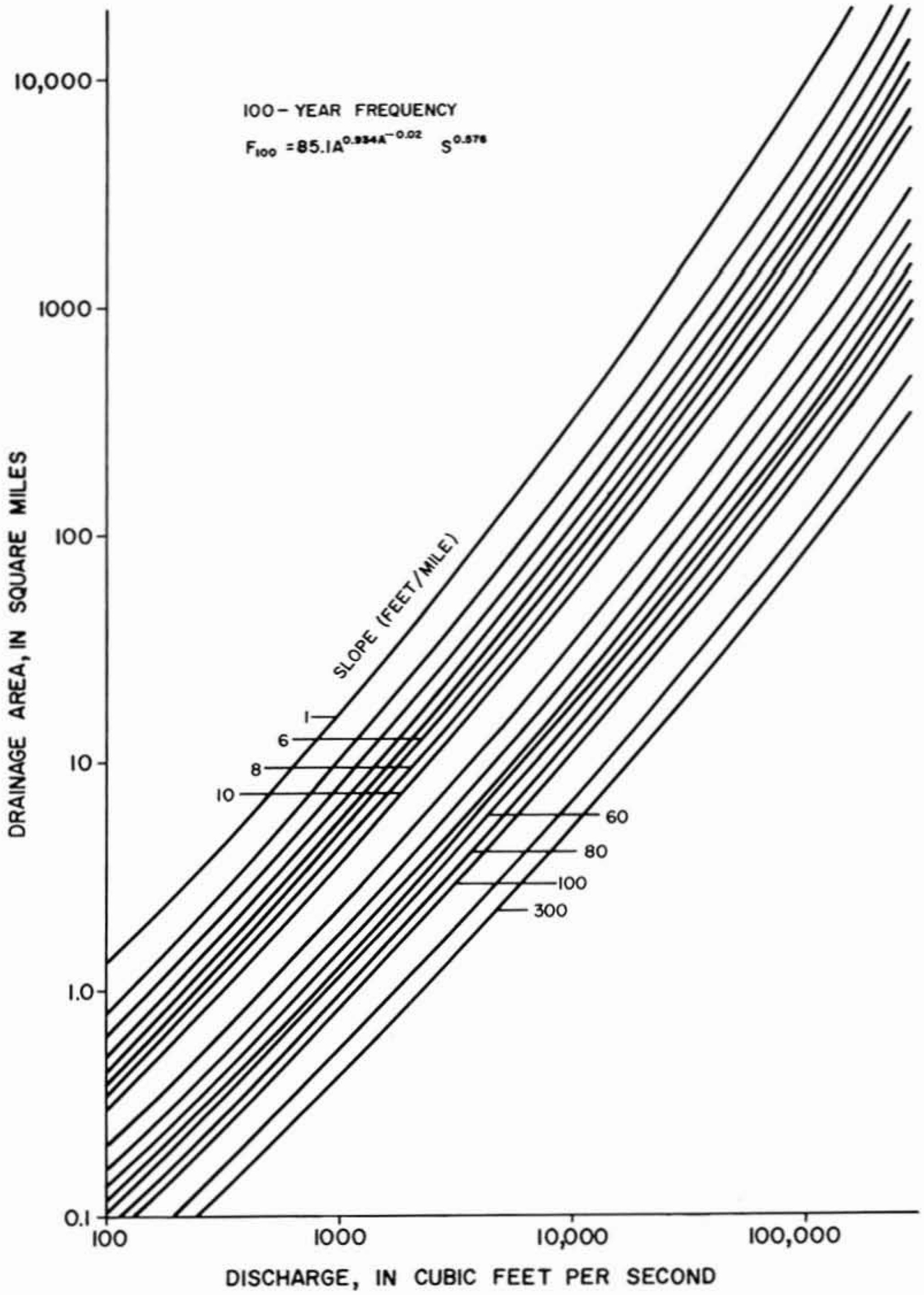


Figure 17

Graphical solution of the 100-year equation.

Table 13

FLOOD-VOLUME FREQUENCY EQUATIONS

[Model is $Y=aA^{b_1}E^{b_2}R^{b_3}Si^{b_4}$; units are Y=acre-feet, A=square miles, E=thousands of feet (for example, 1,200 feet=1.2 in thousands of feet), R=inches, and Si=inches; data in Part A are for periods of less than 1 day for small drainage basins; data in Part B are for periods of 1 to 30 days for all drainage basins.]

PART A

Flow characteristic Y	Regression constant a	Exponent of basin characteristics: Drainage area A	Mean basin elevation E	Mean runoff R	Soils index Si	Standard error of estimate (percent)
$V_{.25,2}$	64	0.70	-1.20	--	--	52
$V_{.25,10}$	126	.84	--	--	--	41
$V_{.25,25}$	182	.88	--	--	--	42
$V_{.25,50}$	214	.93	--	--	--	45
$V_{.25,100}$	240	.97	--	--	--	51
$V_{.50,2}$	74	.77	-1.19	--	--	51
$V_{.50,10}$	142	.92	--	--	--	40
$V_{.50,25}$	189	.96	--	--	--	40
$V_{.50,50}$	233	1.01	--	--	--	45
$V_{.50,100}$	271	1.03	--	--	--	49
$V_{.75,2}$	75	.79	-1.27	--	--	52
$V_{.75,10}$	168	.90	--	--	--	36
$V_{.75,25}$	198	1.05	--	--	--	47
$V_{.75,50}$	225	1.08	--	--	--	50
$V_{.75,100}$	270	1.10	--	--	--	52

Equations are defined by data from streams with drainage areas of 0.2 to 42 square miles. Data from 28 gaging stations were used to compute the equations.

PART B

Flow characteristic Y	Regression constant a	Exponent of basin characteristics: Drainage area A	Mean basin elevation E	Mean runoff R	Soils index Si	Standard error of estimate (percent)
$V_{1,2}$	70	0.86	--	--	--	42
$V_{1,10}$	157	.86	--	--	--	30
$V_{1,25}$	228	.85	--	--	--	33
$V_{1,50}$	296	.84	--	--	--	39
$V_{1,100}$	362	.84	--	--	--	42
$V_{3,2}$	83	.94	--	--	--	38
$V_{3,10}$	535	.96	--	--	-0.94	27
$V_{3,25}$	236	.95	--	--	--	34
$V_{3,50}$	296	.95	--	--	--	40
$V_{3,100}$	361	.95	--	--	--	47
$V_{7,2}$	31	.97	--	.47	--	34
$V_{7,10}$	713	.98	--	--	-1.00	29
$V_{7,25}$	314	.96	--	--	--	39
$V_{7,50}$	395	.95	--	--	--	46
$V_{7,100}$	493	.94	--	--	--	55
$V_{15,2}$	113	1.01	--	--	--	47
$V_{15,10}$	88	.99	--	.43	--	31
$V_{15,25}$	384	.97	--	--	--	44
$V_{15,50}$	483	.97	--	--	--	50
$V_{15,100}$	609	.96	--	--	--	60
$V_{30,2}$	34	1.01	--	.60	--	34
$V_{30,10}$	96	1.01	--	.48	--	31
$V_{30,25}$	450	1.00	--	--	--	43
$V_{30,50}$	565	.99	--	--	--	55
$V_{30,100}$	696	.98	--	--	--	66

Equations are defined by data from streams with drainage areas of 0.2 to 3,800 square miles. Data from 55 gaging stations were used to compute the equations.

recurrence interval of 25 years. Also shown in the table are the drainage area sizes for which the equations are applicable and the standard error of estimate for each equation.

The flood-peak and flood-volume equations are applicable only to unregulated streams with natural channels and insignificant flow losses.

In many instances, stage-frequency information is of vital importance in the location of structures on or near the floodplains of streams. Generalized stage-frequency relationships and equations applicable to the Plateaus region of Missouri have been developed by E. E. Gann (written commun., 1974) from gaging-station records. The curves and equations, shown in figure 18, were studied to determine their applicability to streams in the Springfield area. Data from gaging stations in the area were found to be well within the limits of accuracy defined by the standard error for each of the equations. Therefore, the equations and curves may be used to estimate flood-height frequency in the Greene County area and should be especially useful in planning floodplain developments and solving common engineering and landuse problems.

Note that these relationships are applicable only to unregulated streams with natural channels and insignificant flow losses.

The following example illustrates the use of figure 18. Assume that an estimate of the elevation of the 50-year flood is needed for a site on a stream draining 10 miles^2 in eastern Greene County.

Step 1: Determine the elevation of zero flow at the upper end of the first riffle downstream from the site. The point of zero flow will be the deepest point along the riffle. Assume that the elevation of this point is about 1,300 feet above mean sea level.

Step 2: Determine the flood height graphically from figure 18 for a 10-mile^2 drainage area and a 50-year flood to be 11 feet. The same value may be obtained by using the appropriate equation shown on figure 18 ($H_{50}=7.13\ A^{0.179}$).

Step 3: Add the elevation of point of zero flow to flood height from figure 18 and obtain desired elevation of approximately 1,311 feet.

Ungaged Sites in Urban Basins

It is not possible to adjust rural stage-frequency relationships to urban conditions unless precise survey information is available on the location and size of structures on the urban floodplains.

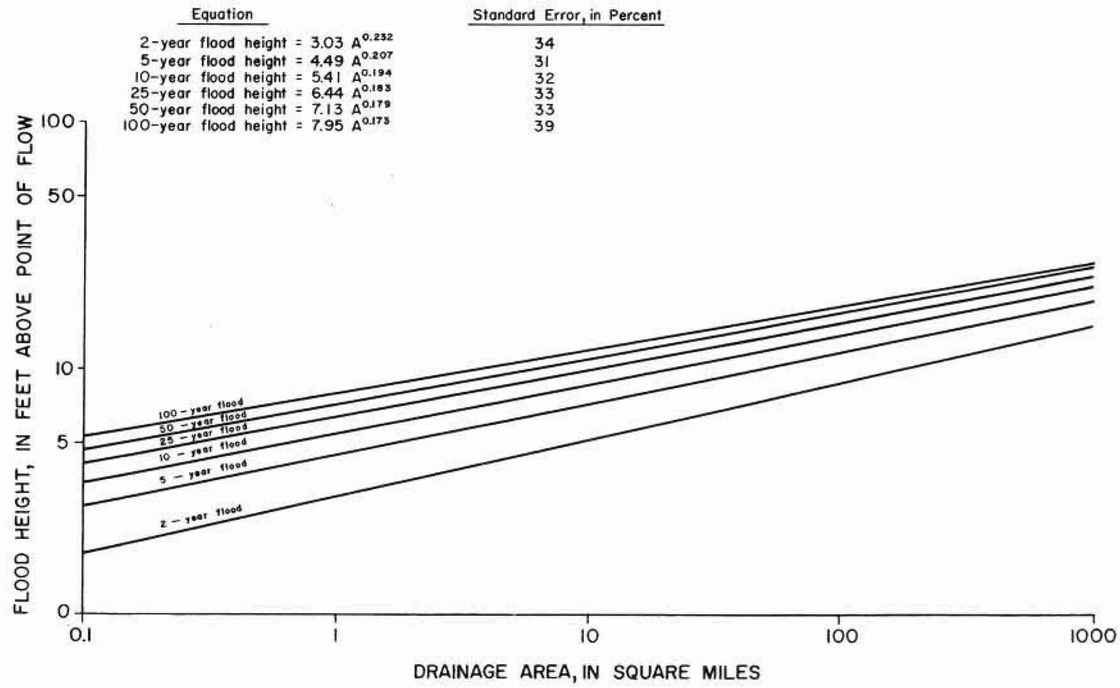


Figure 18

Stage-frequency relations for streams in the Springfield area, Missouri.

However, the changes caused by urbanization in the peak discharge-frequency relationships of table 12 can be estimated by using a method proposed by Gann (1971). This highly generalized method of estimating flood-peak discharge for small (≤50 miles^2) urban basins will be useful to planners and engineers in the Springfield area until more definitive urban runoff data are available.

To utilize this method, four pieces of information are required: (a) the percent of impervious area in the basin, (b) the percent of area served by storm sewers, (c) the area and slope of the basin as defined in the section "Ungaged Sites in Rural Basins", and (d) an estimate of the magnitude of the 2-year recurrence interval flood-peak (see tbl. 12 and fig. 15). These data can be combined and used in the following equation: $Q_x = R_1 R_2 P_2$,

where

Q_x is the magnitude of a flood with x-year recurrence interval, in foot^3/s,

R_1 is the ratio of discharge after urbanization to discharge before urbanization for the 2-year flood, from figure 19,

R_2 is the flood-frequency ratio from figure 20, and

P_2 is the magnitude of the 2-year flood in foot^3/s.

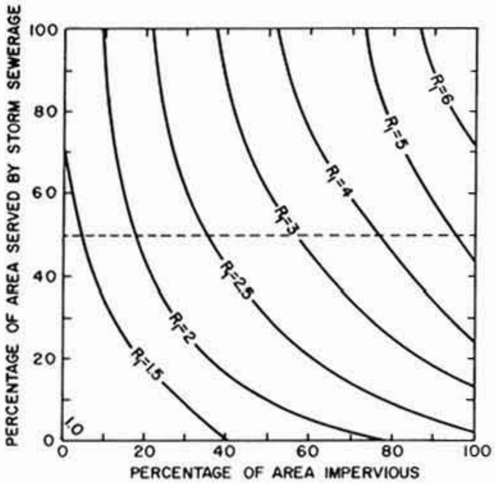


Figure 19

Effect of urbanization on the 2-year flood.
(After Leopold, 1968)

The following example illustrates the use of the procedures for urban basins. Assume that the peak discharge for the 100-year flood is required for a small basin in eastern Greene County where the projected degree of development will be 40-percent imperviousness in the basin and 40 percent of the area served by storm sewers.

Step 1: From a topographic map of the area, determine the drainage area and basin slope. Assume that the drainage area is found to be 10 miles^2 and that the slope is found to be 30 feet/mile.

Step 2: From the equation shown in table 12 or the graphical solution of figure 15, determine the 2-year flood to be $53.5(10)^{0.851}(10)^{-0.02}(30)^{0.356}=$ 1,160 feet^3/s or graphically, 1,200 feet^3/s.

Step 3: Using the projected degree of development, enter figure 19 and select the ratio R_1 to be 2.5.

Step 4: Using the desired recurrence interval and projected degree of imperviousness, enter figure 20 and select the ratio R_2 to be 3.4.

Step 5: Solution of the equation $Q_x= R_1R_2P_2$ is the final step. $Q_{100}=(2.5)(3.4)(1,200)=10,200$ feet^3/s.

In using the preceding procedure for estimating flood peaks for small urban basins, the following limitations should be considered. First, the urban flood-frequency relations are highly generalized and can only provide a rough approximation of the true frequency relation for urban areas. Second, the relationships are applicable only to basins with drainage areas of 0.1 - 50 miles^2. Third, the relationships only apply for complete developments; that is, they should not be used where only a part of the drainage area, such as the upper half or lower half, is expected to be developed.

For further background information and basic assumptions used in developing these relationships, the reader is referred to Gann (1971, p. 15-16).

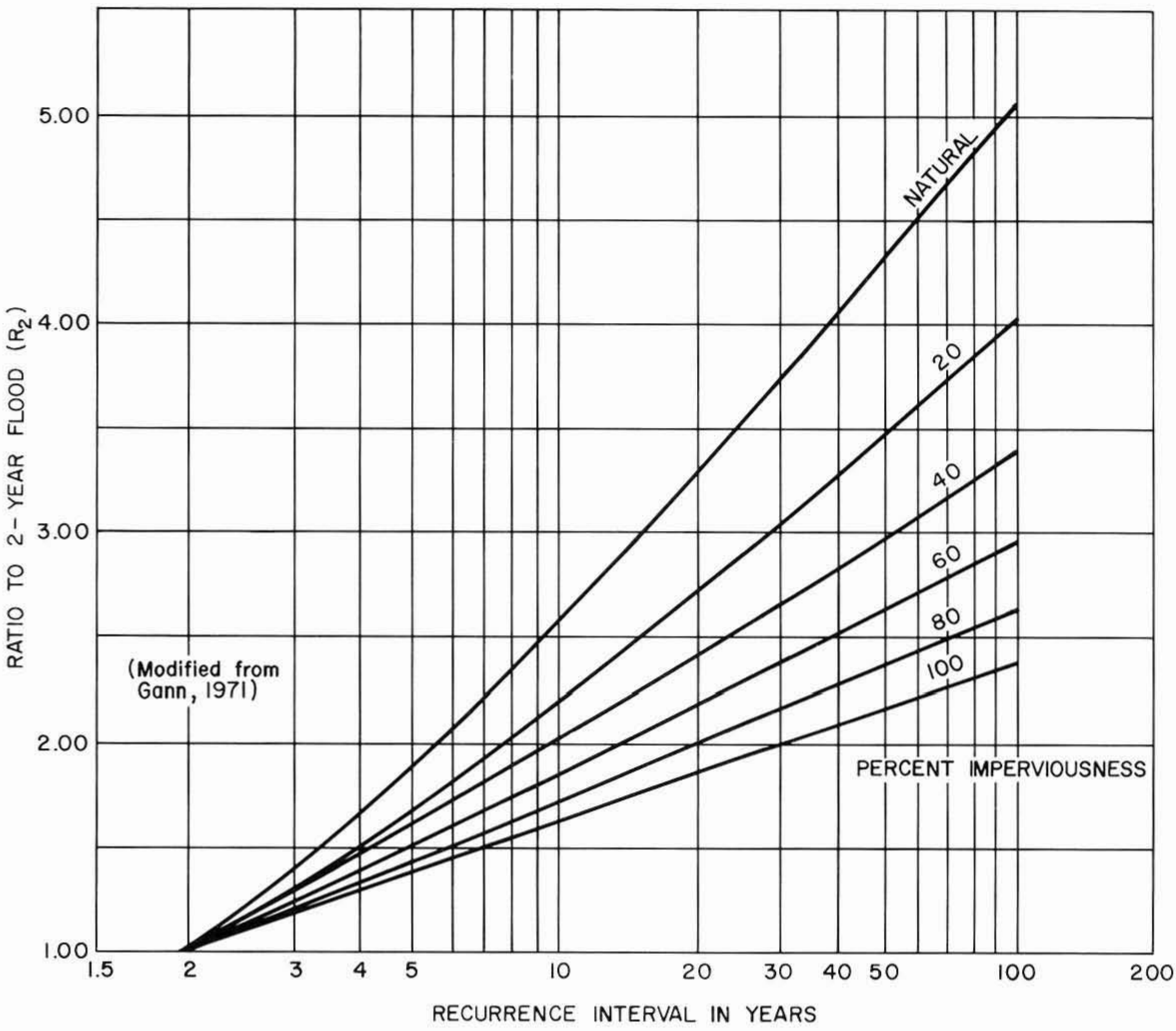


Figure 20

Relation of floods in the Springfield area, Missouri, to the 2-year flood for selected degrees of basin imperviousness.

MEAN FLOWS

One of the most important characteristics to be evaluated in planning the utilization of streamflow is the mean or average flow of the stream. The mean flow is the parameter most indicative of the total potential water supply available and is most important in defining draft-storage requirements at a given point on the stream.

Mean flows are defined from long-time continuous records at streamgaging stations. However, it is not feasible to operate gaging stations at all sites for which flow data may be required, so mean-flow data from many stations are generalized in terms of basin characteristics in order to provide estimates at ungaged sites.

Figure 21 is a graphical presentation of a generalized equation for computation of mean streamflows in the Springfield area. The relationship was developed by using data from 40 continuous-record stations in the Ozarks region of Missouri. Note that data from stations in the project area are plotted on the graph to confirm its applicability to the range of stream sizes in the area.

In some basins in the Springfield area, the regionalization procedure of figure 21 will not give satisfactory results because of excessive water losses to cavernous limestone formation. Many of the stream reaches where regionalization procedures are not adequate because of this condition are indicated in the section on seepage-run information and in figures 9 to 14.

In urbanized basins, the percentage of impervious area is greatly increased, and this in turn increases mean flows. Note in figure 21 that data from urban basins plot above the average regression line in all cases. In studies throughout the United States, it has been shown that annual runoff can be increased two to three times by significant urbanization (Miller and others, 1974; Crippen and Waananen, 1969). However, until more comprehensive urban runoff data are available, specific recommendations cannot be made for adjusting data from figure 21 for urbanization effects in the Springfield area.

DRAFT-STORAGE REQUIREMENTS

When surface-water supplies larger than those provided by unregulated streamflow are required, storage reservoirs are needed. Water can then be stored during periods of excessive runoff for later use.

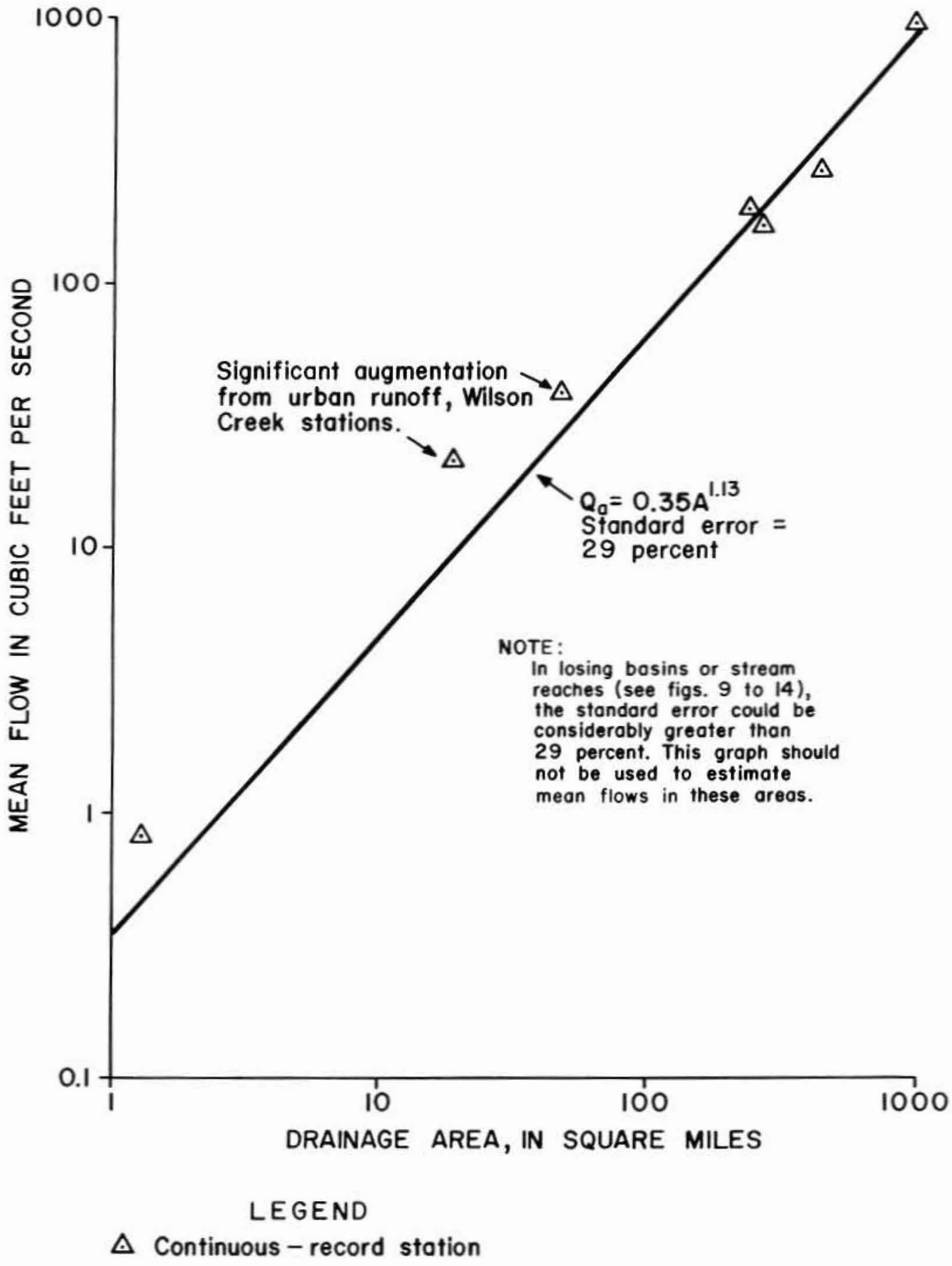


Figure 21

Method of estimating mean flow for ungaged streams in the Springfield area, Missouri.

Extensive analyses of storage requirements were not attempted during the study of hydrologic characteristics of streams in the Greene County area. However, station data and regional draft-storage relationships from statewide within-year and carryover storage analyses (Skelton, 1968 and 1971) were checked and found applicable to streams in the project area. It is recommended that the procedures shown in those reports be used when storage problems are encountered.

The user must remain aware that caution has to be exercised when using regionalization procedures in cavernous limestone such as that in the Springfield area. Many streams or reaches where flow is lost or deficient have been delineated in figures 9 to 14, but others may exist. Thorough hydrologic and geologic site studies must be made prior to construction to avoid gross underestimation of storage requirements and excessive seepage losses.

For the readers' convenience, draft-storage data at continuous- and partial-record stations in the Springfield area are shown in table 14.

QUALITY OF SURFACE WATER

Water-quality data have been collected from two sites on the James River and one site on Finley Creek (pl. 1, map nos. 145, 174, and 204) since August 1967. These data were published in the annual report series entitled, "Water Resources Data for Missouri" (U. S. Geol. Survey, 1968-1975). A summary of the total dissolved-solids concentration of water samples collected from these sites between October 1967 and November 1974 is given in table 15.

A graphical comparison of analyses of water from these three sites (fig. 22) shows the similarity of water from the James River (map no. 145) and Finley Creek (map no. 204). The diagram for the James River near Boaz shows the effect of sewage effluent and urban runoff from the Wilson Creek basin. Water in this part of the James River and Finley Creek is of the calcium bicarbonate type reflecting the limestone terrane through which both streams flow. A comparison of figure 22 with figure 7 will show the similarity of the surface water to water from the minor aquifer.

Table 14

DRAFT-STORAGE DATA FOR CONTINUOUS- AND PARTIAL-RECORD STATIONS

Map number (pl.1)	Station name and number	Record used in analysis	Drainage area (mi^2)	Average annual runoff (in)	[a]Chance of deficiency (percent)	Amount of storage (in thousands of acre-feet) for draft rate (in ft^3/s) indicated in column headings (not corrected for reservoir evaporation, sedimentation, and seepage)				
36	Sac River at Ash Grove (06918420)	(b)	(c)	11.0		13 ft^3/s	26 ft^3/s	52 ft^3/s	65 ft^3/s	90 ft^3/s
					2	6	16	51	78	230
					5	4	9	32	52	159
					10	3	6	21	43	124
46	Clear Creek near Phenix (06918430)	(b)	(c)	11.0		5 ft^3/s	10 ft^3/s	20 ft^3/s	30 ft^3/s	35 ft^3/s
					2	3	6	19	47	89
					5	2	4	12	38	61
					10	1	3	8	27	47
130	James River near Springfield (07050700)	1956-74	246	12.0		50 ft^3/s	75 ft^3/s	125 ft^3/s	170 ft^3/s	195 ft^3/s
					2	38	66	190	424	---
					5	15	33	130	320	540
					10	11	22	100	250	400
144	James River below Battlefield (07051500)	(b)	(c)	12.0		66 ft^3/s	98 ft^3/s	164 ft^3/s	195 ft^3/s	230 ft^3/s
					2	50	87	245	360	540
					5	24	45	172	290	420
					10	15	30	128	210	330
203	Finley Creek near Ozark (07052300)	(b)	(c)	13.0		44 ft^3/s	66 ft^3/s	110 ft^3/s	154 ft^3/s	176 ft^3/s
					2	30	56	150	325	---
					5	14	28	110	250	400
					10	6	16	82	200	310

[a]Percent of years in which a storage reservoir of indicated capacity would become empty.

[b]Carryover storage requirements for this partial-record site were computed from regional curves. Within-year storage requirements are shown in Water Resources Report No. 22.

[c]Rough drainage area (± 10 percent) is available but not shown. A subsequent report will contain planimetered drainage area data for the state.

Partial-chemical analyses of water from streams and springs measured during a low-flow period are listed in table 16. These data show the relation of rock type in which the stream is incised to the quality of water in the stream. For example, the sample from Pomme de Terre River (tbl. 16, map no. 80) is a calcium-magnesium bicarbonate type of water reflecting the underlying dolomite bedrock upstream from that site. Analyses from the upper ends of the James River (tbl. 16, map no. 96) and Finley Creek (tbl. 16, map no. 193) show a mixed-type of water because even though the streams at those points are underlain by dolomite they also receive much water from tributary streams and springs that are underlain by limestone. Further downstream both streams flow on limestone; this is reflected in the chemical composition of the water (fig. 22).

Table 15

SUMMARY OF TOTAL DISSOLVED-SOLIDS CONCENTRATION FOR THE JAMES RIVER AND FINLEY CREEK

(Results in milligrams per liter)					
Site	Map No.	Number of Samples	Maximum	Minimum	Mean
James River	145	83	232	130	191
James River	174	84	387	141	240
Finley Creek	204	84	228	138	182

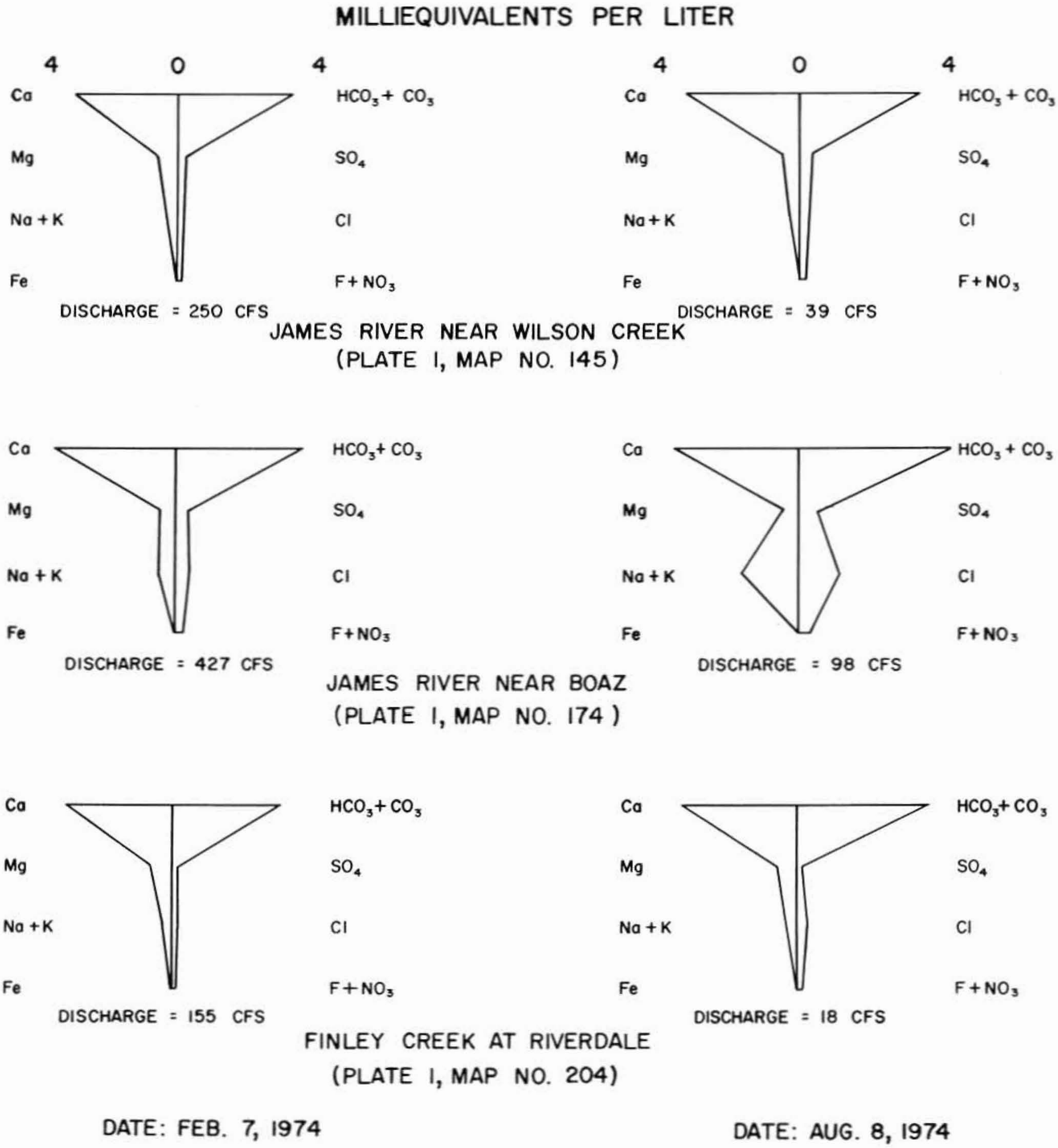


Figure 22

Comparison of chemical analyses of water from the James River and Finley Creek.

Table 16

PARTIAL-CHEMICAL ANALYSES OF WATER FROM STREAMS AND SPRINGS MEASURED DURING A LOW-FLOW PERIOD

Data in milligrams per liter except as indicated

Map number (pl. 1)	Station name	Date of collection	Discharge (ft^3/s)	Temperature (°C)	Specific conductance (micromhos at 25°C)	Calcium (Ca)	Magnesium (Mg)	pH (units)	Chloride (Cl)	Total phosphorus as P	Total nitrogen as N	Organic nitrogen as N	Ammonia nitrogen as N	Nitrite as N	Nitrate as N	Ca/Mg (ratio in epm)
3	Sac River	08-22-74	4.1	22.0	400	67	3.5	8.0	8.8	0.06	3.8	0.33	0.06	0.07	3.3	11.6
31	Pickerel Creek	08-22-74	14	18.0	410	65	7.0	7.6	8.4	.04	3.4	.26	.01	.01	3.1	5.6
32	Pickerel Creek Tributary	08-22-74	.30	15.5	480	78	10	7.8	18	.03	3.0	.03	.00	.00	3.0	4.7
40	Brower Spring	08-22-74	.60	15.0	440	77	5.7	7.4	16	.03	3.8	.15	.01	.00	3.6	8.2
42	Clear Creek	08-22-74	8.7	22.0	385	70	6.1	7.8	9.3	.04	1.8	.20	.04	.00	1.6	7.0
59	South Dry Sac Creek	08-22-74	2.8	19.0	370	65	7.8	7.6	15	.04	2.0	.24	.06	.00	1.7	5.1
63	Spring Branch	08-22-74	5.0	15.5	540	100	4.5	7.7	21	.05	3.6	.12	.12	.06	3.3	13.5
75	Cave Spring	08-22-74	.30	14.0	490	87	8.1	7.1	7.8	.02	2.9	.17	.02	.00	2.7	6.5
80	Pomme de Terre River	08-23-74	1.5	24.0	335	37	20	8.0	9.2	.06	.45	.29	.03	.00	.13	1.1
82	South Fork Pomme-de Terre River	08-23-74	3.5	24.0	315	50	9.6	7.8	11	.03	.46	.13	.02	.00	.31	3.2
83	Pomme de Terre River	08-23-74	6.0	24.5	360	43	19	8.0	10	.03	.39	.14	.03	.00	.22	1.4
90	Little Pomme de Terre River	08-23-74	0.30	22.5	395	47	23	7.3	13	0.03	0.49	0.19	0.04	0.00	0.26	1.2
96	James River at Highway A	08-19-74	3.4	22.0	320	41	12	7.6	14	.02	.46	.02	.05	.00	.39	2.1
104	Panther Creek on County Highway B	08-19-74	4.0	22.0	342	41	16	7.6	6.7	.02	.63	.11	.03	.00	.49	1.6
110	Sawyer Creek	08-19-74	1.1	21.0	352	53	10	7.8	9.3	.05	.90	.08	.04	.00	.78	3.2
111	James River at Highway 125	08-20-74	18	21.0	330	45	14	7.6	8.5	.03	.39	.05	.05	.02	.27	2.0
117	Turner Creek at Turner	08-20-74	1.7	18.5	365	58	5.4	7.6	11	.04	2.2	.13	.03	.00	2.0	6.5
119	Pearson Creek	08-20-74	3.6	16.0	400	66	6.3	7.6	14	.04	2.9	.38	.03	.01	2.5	6.4
121	Pearson Creek	08-20-74	4.8	20.0	410	67	5.7	7.7	14	.05	2.2	.16	.03	.00	2.0	7.1
124	Pearson Creek	08-20-74	1.5	18.0	415	60	5.0	7.3	12	.08	2.5	.22	.01	.00	2.3	7.3
129	Pearson Creek at the mouth	08-20-74	9.6	21.0	450	75	5.1	7.8	13	.07	2.9	.36	.02	.01	2.5	8.9
132	Sequiota Spring	08-20-74	2.3	17.0	460	75	4.1	7.0	14	0.14	2.6	0.33	0.18	0.01	2.1	11.1
135	Camp Cora Spring	08-20-74	3.0	16.0	440	85	1.8	7.2	12	.07	2.9	.02	.02	.00	2.9	28.5
143	Blue Spring	08-20-74	4.5	14.0	440	81	1.5	7.0	7.5	.04	3.9	.03	.02	.01	3.8	32.5
153	Shuyler Creek	08-21-74	.40	19.0	415	75	1.3	---	9.8	.05	3.0	.18	.01	.02	2.8	35
166	Terrell Creek at Highway ZZ	08-20-74	6.5	20.0	420	68	2.2	7.5	9.4	.07	3.5	.34	.07	.01	3.1	18.7
173	Young Spring Branch	08-21-74	.10	18.0	420	75	3.2	7.6	11	.04	3.6	.08	.02	.00	3.5	14.2
175	McCafferty Hollow Spring	08-21-74	.70	20.5	460	88	1.6	6.8	10	.04	3.8	.34	.10	.02	3.4	33.3
193	Finley Creek	08-21-74	9.0	26.0	320	40	14	7.5	8.2	.03	.63	.31	.05	.00	.27	1.7
194	Patterson Spring	08-21-74	11	14.0	360	49	10	7.3	7.3	.02	1.4	.03	.03	.00	1.3	3.0
202	Parched Corn Hollow	08-21-74	1.3	20.8	377	70	3.4	7.6	8.6	.05	3.2	.36	.02	.00	2.8	12.5
203	Finley Creek near Ozark	08-21-74	36	24.5	320	46	9.8	7.3	7.7	.03	.83	.10	.04	.00	.69	2.9

CONTAMINATION OF THE WATER RESOURCE

EFFECTS OF URBAN RUNOFF ON WATER QUALITY

Water-quality monitors were installed in cooperation with the City of Springfield, on Wilson Creek near Springfield, near Battlefield, and on the James River near Boaz during the fall of 1972 (pl. 1). Table 17 and figure 23, prepared by James H. Barks (written commun., 1974), summarize some of the more pertinent data collected at these sites.

Table 17 shows the values for temperature, specific conductance, dissolved oxygen, and pH that were observed at the stations, all of which are affected to some extent by urbanization. The upstream station on Wilson Creek is affected by runoff from the City of Springfield; the downstream station near Battlefield is additionally affected by effluent from the Southwest Sewage Treatment Plant. At the Boaz station on the James River, the runoff from the city can seriously affect the dissolved oxygen content of the water, as shown in figure 23.

A study of hydrologic conditions prior to June 4, 1974, shows that the rise depicted in figure 23 marked the first runoff of any consequence for several weeks. Also, it is evident from figure 23 that runoff from Wilson Creek basin was responsible for the small rise on the James River on June 5, 1974, because any concurrent headwater flooding in the James River would have caused much greater peaks at the Boaz station. The fact that dissolved oxygen declined from 4.2 to 2.8 mg/1 in the James River during these small rises shows that this particular volume of urban runoff was of poor quality. This is substantiated by similar significant drops in dissolved oxygen at the Wilson Creek stations.

On the other hand, the runoff in the basins from a much greater rise on June 7 did not cause reductions in dissolved oxygen because the June 4 rise had flushed the urban areas and stream channel, thus assuring improved quality of any storm runoff in the immediate

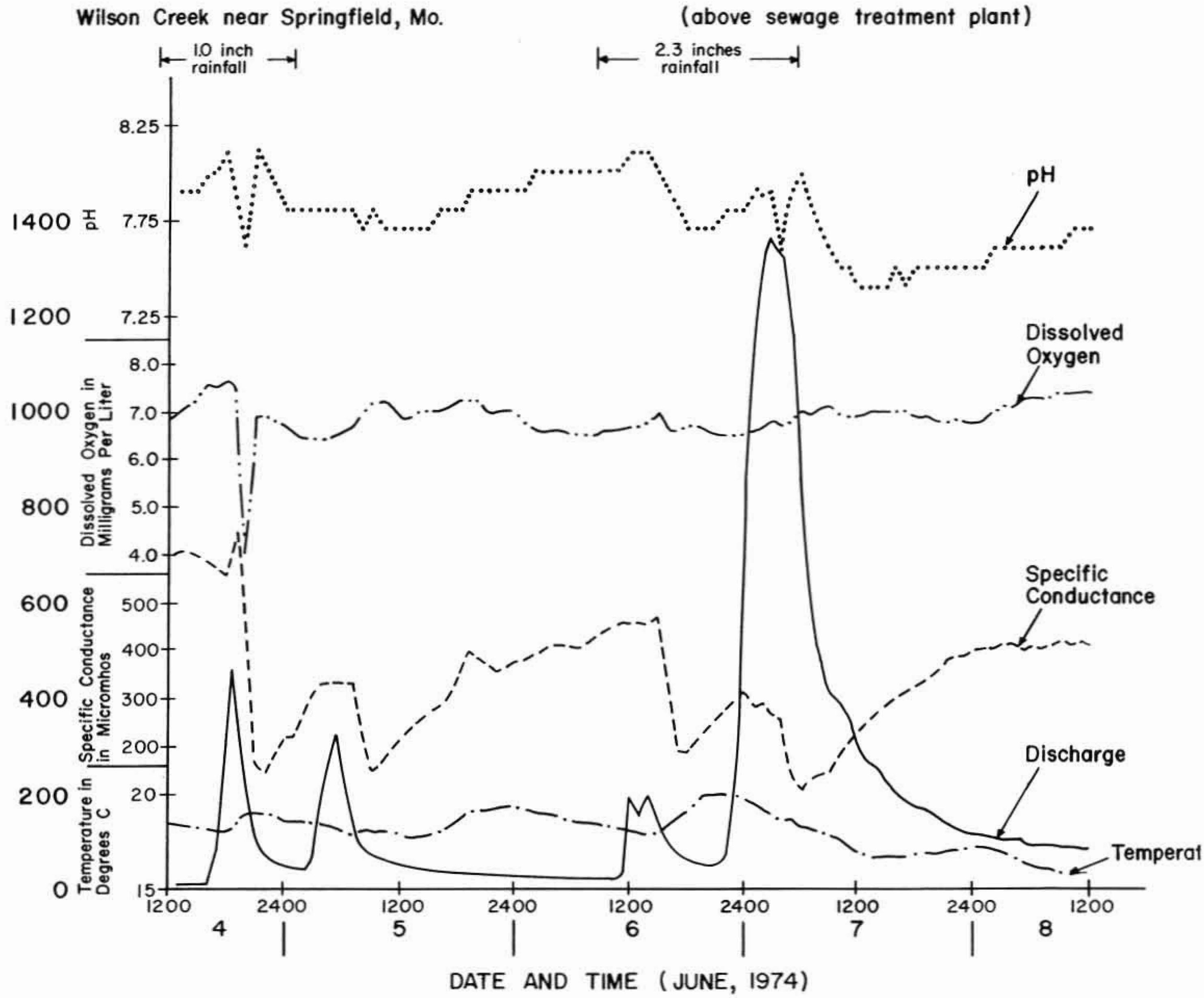


Figure 23

Effects of urban runoff on water-quality parameters in Wilson Creek and James River.

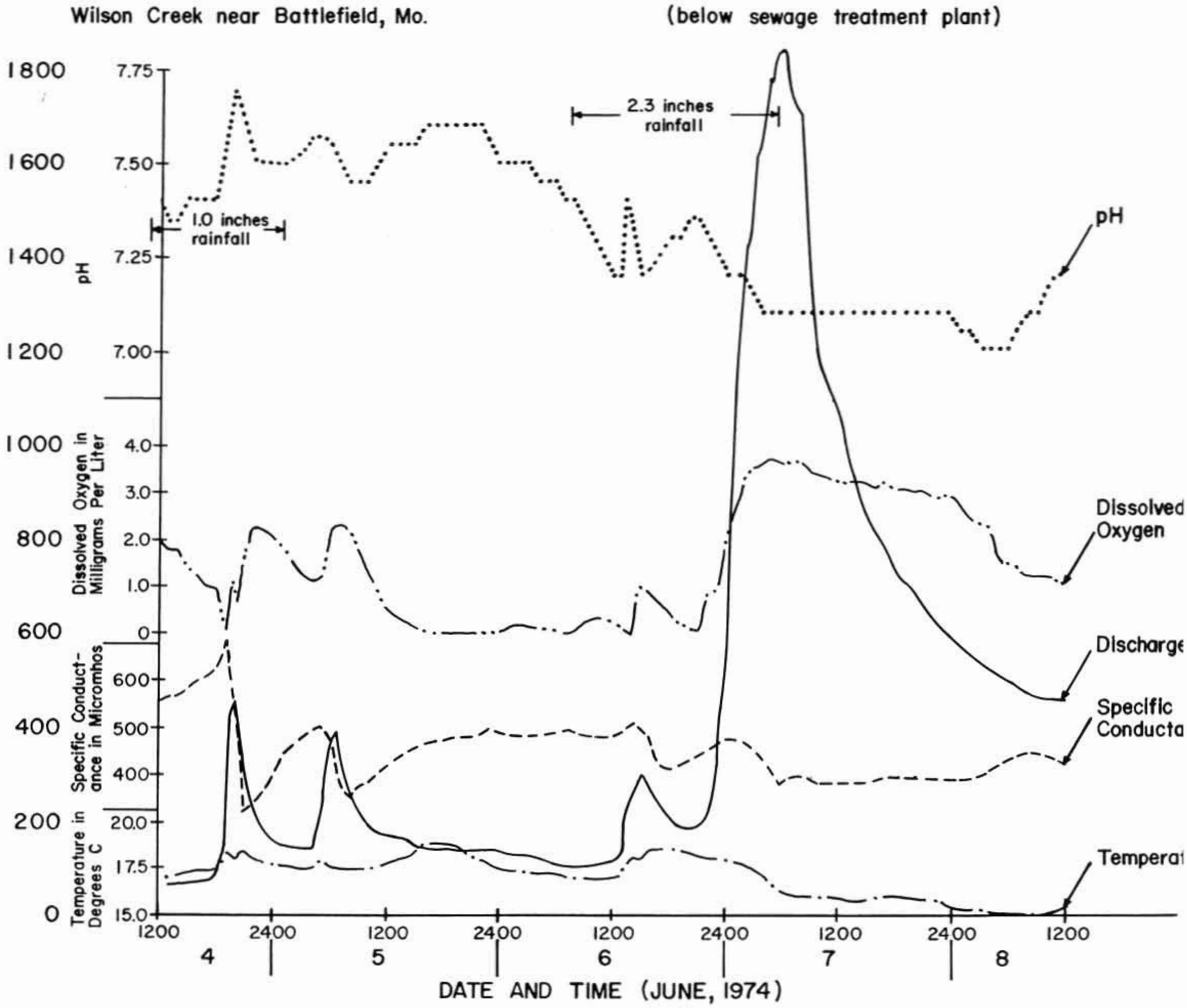


Figure 23 (continued).....

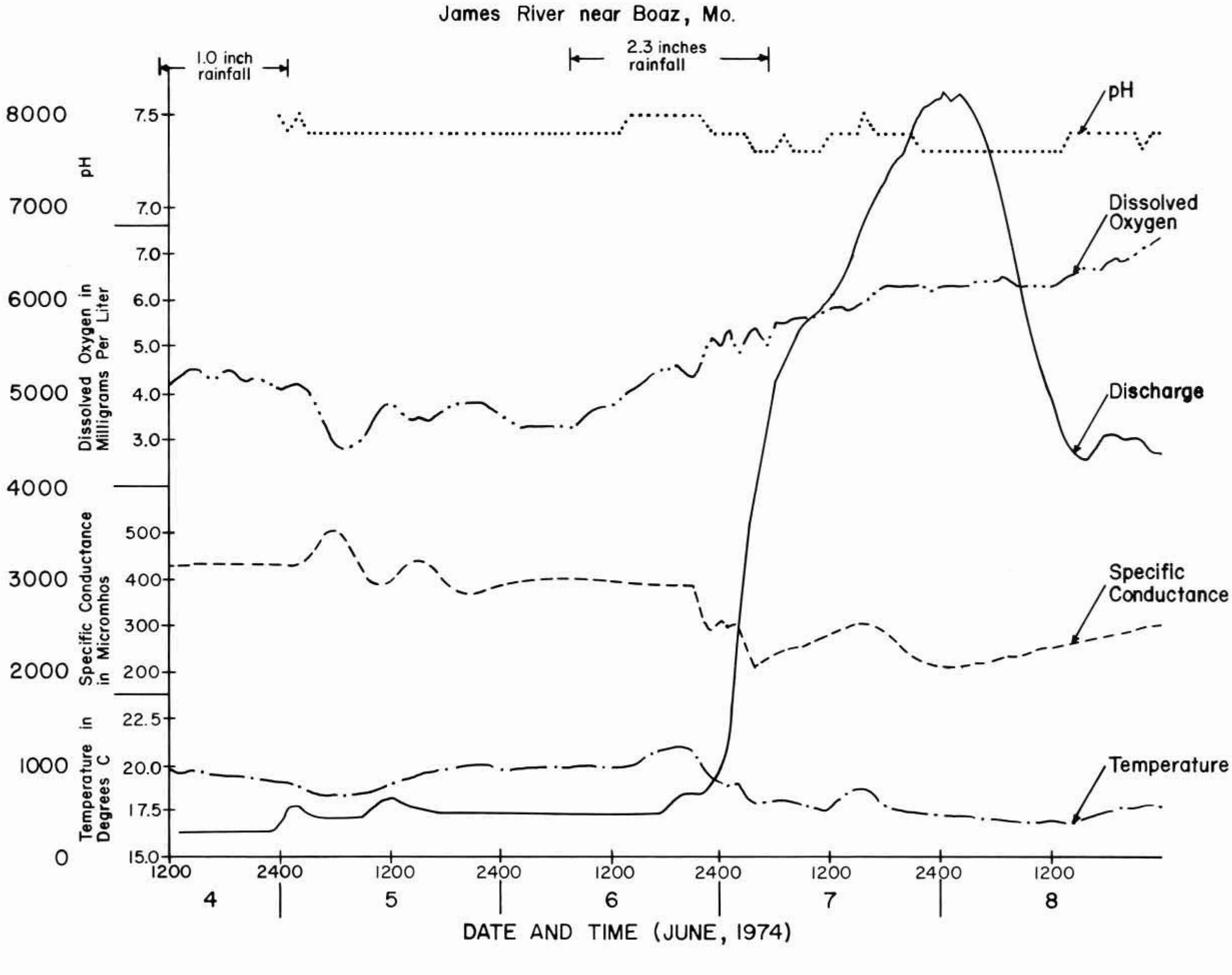


Figure 23 (continued).....

Table 17

SUMMARY OF DATA COLLECTED AT WATER-QUALITY STATIONS

Map Number 147 (pl. 1, tbl. 7)
07052100 Wilson Creek near Springfield, Missouri, upstream from sewage plant
Period of record - October 1972 to June 1974

Parameter	Percent Usable Record	Maximum	Minimum
Temperature	89	28.0	0.0
Specific conductance	85	1,160	90
Dissolved oxygen	77	19.4	0.0
pH	61	9.2	7.0

Map Number 151 (pl. 1, tbl. 7)
07052160 Wilson Creek near Battlefield, Missouri, downstream from sewage plant
Period of record - October 1972 to June 1974

Parameter	Percent Usable Record	Maximum	Minimum
Temperature	87	25.5	7.5
Specific conductance	87	904	112
Dissolved oxygen	81	11.3	0.0
pH	71	8.4	6.5

Map Number 174 (pl. 1, tbl. 7)
07052250 James River near Boaz, Missouri
Period of record - October 1972 to June 1974

Parameter	Percent Usable Record	Maximum	Minimum
Temperature	74	28.5	2.0
Specific conductance	71	795	120
Dissolved oxygen[1]	60	12.4	2.4
pH	71	8.5	6.8

[1]Dissolved oxygen recorder inoperative during July and August 1973.

future. Examination of all data collected at the three sites shows that the initial flush of storm runoff following several weeks of stable conditions invariably produced similar results.

The implication of these data for water-management practices is significant. These data tend to substantiate research by Shaeffer and Zeizel (1966, p. 73 and fig. 31) that showed, at least for some streams, that only the initial flush of a flood is polluted. In the upper reaches of Wilson Creek, upstream from the sewage treatment plant, the water could be stored for later beneficial use after the first few hours of flooding. Downstream from the treatment plant, however, this would not be feasible because of sludge accumulation in the stream bottom and the possibility of untreated sewage bypassing the treatment plant during storms.

POTENTIAL FOR GROUNDWATER CONTAMINATION

Over the years health officials in Greene County have compiled results of thousands of bacteriological tests of water from private wells in the area. These records were made available to the authors, and records beginning in 1969 were used during the course of this study. The locations of wells showing questionable or "unsafe" bacteriological water-quality analyses for the time period (1969-75) were plotted on a map of Greene County.

Any clustering of points in a restricted geographical area was noted for further study. Water samples were collected on May 20, May 21, and June 25, 1975, in four areas where clustering of unsafe bacteriological samples had been noted. The water samples collected were analyzed for chemical properties that would indicate pollution, and the depth, amount of casing, and aquifer unit of each well were noted (tbl. 5). The chemical constituents used for this evaluation included chloride, phosphorus, nitrogen, bicarbonate, calcium, and magnesium. The last three were used as indicators of the rock type from which each water sample came. Most of the wells sampled were private, domestic wells. A few were relatively low-yield, industrial wells and one was a public water-supply well. Depths of the wells ranged from 32 feet to 600 feet, with casing depths ranging from 0 to 370 feet. These wells were completed in geologic horizons ranging from the Roubidoux Formation, of Ordovician age, to the Burlington Limestone, of Mississippian age.

Table 5 shows the water quality for the samples from the four "cluster" areas. Of the 33 wells sampled in the May-June 1975 period, water from 2 wells contained nitrate nitrogen in excess of 10 mg/1. It has been stated (Brown and others, 1970, p. 119) that, "Cyanosis due to methemoglobinemia may occur in infants whose drinking of formula water contains a high concentration of nitrates. The nitrates, when ingested, are converted to nitrites in the digestive system of some infants. The nitrite ion oxidizes hemoglobin to methemoglobin, and thereby causes cyanosis". Consequently, it has been recommended that water containing more than 10 mg/1 nitrate nitrogen should not be used in infant feeding (Comly, 1945). Table 5 also shows the water quality for samples collected from wells during February-March 1974. Water from one of those wells had a nitrate nitrogen concentration in excess of 10 mg/1.

Some wells in the Springfield area have been contaminated with gasoline, fuel oil, and other objectionable fluids (oral commun., Joseph Harmon, Greene County Public Health Office, 1973). In most cases, these pollutants did not travel far from the point of origin before entering individual water-supply wells. In almost every instance, the contaminated wells were poorly constructed or had insufficient casing.

A dramatic instance of groundwater contamination occurred on October 29, 1968, when the bottom of the waste-stabilization lagoon at Republic, Mo. collapsed into a sinkhole-cave conduit system. All of the material in this 4.9-acre lagoon drained into the shallow groundwater horizons. Several springs and wells, down gradient (southeast) of the lagoon, received effluent from the collapsed structure. A dye-trace test conducted by the Engineering Geology Section of the Missouri Division of Geology and Land Survey on March 5, 1969, showed dye in private wells southeast of the collapse area.

Another well, northwest of Republic, just downstream from another operating lagoon, showed traces of dye from another dye-trace test conducted on January 29, 1970. Dye was introduced into the effluent overflow of Republic's Northwest Sewage Lagoon by the Missouri Division of Geology and Land Survey, and was subsequently recovered from the well. The well was completed at a depth of 304 feet in the Jefferson City Dolomite and 300 feet of casing was set. The casing was not grouted or sealed to prevent shallow ground water from the Burlington Limestone from flowing down the outside of the casing into the deeper groundwater zones.

It is apparent from data gathered during the well-inventory and well-sampling phases of this investigation, and from discussions with Greene County Public Health Office (oral comm., Joseph Harmon, 1973), that improperly constructed and improperly cased wells penetrating the deeper aquifer zones create a hazard to the water system which cannot be ignored. This, coupled with the fact that water leaking from the minor aquifer and moving downward through the Northview Formation, may pollute the major aquifer if measures are not adopted to protect it.

WATER USE

PRESENT USE

Estimates of water use in the study area are shown in table 18. The 15.4 Mgal/d of surface water shown for the public water-supply category is the reported average daily consumption for the City of Springfield (1973). Although shown under the surface-water category, a large portion of Springfield's supply comes from Fulbright Spring--as much as 60 percent at times. The city also has deep wells which served as an auxiliary supply in the past, but which will no doubt be used as the demand for water grows.

In addition, the city has acquired three deep wells, two of which served the Park Crest area and one served the Orchard Crest area. These wells will also be used as part of the municipal supply. The 1.3 Mgal day of ground water for public supply is pumped from the major aquifer by the towns of Nixa, Republic, Ozark, Willard, Rogersville, Strafford, Clever, Sparta, and by Public Water Supply District 1 (Battlefield). Also included under the public water-supply category are subdivisions and trailer parks that have their own water supplies. Rural domestic use was estimated from census figures and a per capita daily use of 50 gallons. Self-supplied industrial use is determined from figures supplied by plant managers and, in some instances, estimated from pump capacities and lengths of operation.

SPRINGFIELD'S PRESENT (1976) WATER SUPPLY

How dependable is the present (1976) water supply of Springfield? Is prompt expansion urgently needed to forestall water shortages during severe droughts or can the city proceed deliberately and carefully in developing additional supplies to provide for future growth? These and related questions prompted

Table 18

WATER USE IN THE SPRINGFIELD AREA

Use	Source and Amounts (mgd)	
	Surface Water	Ground Water
Public water supply	*15.4	**1.3
Rural domestic use	----	**1.3
Self-supplied industrial	----	5.4
Total	15.4	8.0

*Division of Environmental Quality, 1974, Census of public water supplies in Missouri, 1973: Missouri Department of Natural Resources.

**Estimated

the authors to compute the amount of water currently in storage in surface-water reservoirs and to analyze the dependability (yield) of the existing city water supply during a hypothetical, multi-year drought.

First, using information from Burns and McDonnell (1971), a computation was made to determine the time that would be needed at current usage rates to deplete the amount of water in storage in McDaniel and Fellows Lakes; assuming no rainfall, full reservoirs at the beginning of the computation period, and average evaporation rates from a full lake with constant surface area:

a. Daily water use (1976) is estimated by City Utilities to be 15 Mgal/d.

b. Storage capacity of lakes (excluding storage allocated to siltation and conservation):

McDaniel	$1.4\text{X}10^9$ gal
Fellows	$8.5\text{X}10^9$ gal
Total =	$9.9\text{X}10^9$ gal

c. Average annual lake evaporation equals 42 inches.

d. Surface area of lakes when full equals 1,120 acres.

e. $\frac{42 \text{ in/yr}}{12 \text{ in/ft}} \text{X} 1,120 \text{ acres X} 0.326 \frac{\text{million gal}}{\text{acre-ft}} = 1.28\text{X}10^9$ gal/yr.

f. $\frac{1.28\text{X}10^9 \text{ gal/yr}}{365 \text{ d/yr}} = 3.5$ Mgal/d evap. loss.

g. Daily use plus evaporation loss = 15 Mgal/d+3.5 Mgal/d=18.5 Mgal/d.

h. $\frac{9.9X10^9 \text{ gal}}{18.5X10^6 \text{ gal/d}}$=0.535X10^3=535 days = 1.5 years to deplete storage in McDaniel and Fellows Lakes.

These estimates are quite conservative because of the limiting assumptions of no rainfall during the period and constant (rather than shrinking) surface area for evaporation estimates. To illustrate the conservative nature of the estimates, the longest dry period (0.2 inch or less in any day) experienced at Springfield since precipitation records began was 63 days during the summer of 1953 (Decker, 1958). This represents only 12 percent of the 535-day dry period shown in step h

Regional draft-storage curves (Skelton, 1971, p. 7) were utilized to estimate maximum draft rates from existing surface-storage reservoirs (Fellows and McDaniel Lakes) during a severe multi-year drought. The reported capacity of nine deep wells that are part of the Springfield water system as well as the estimated low flow of Fulbright Spring were also included in the analysis. Table 19 summarizes the computations and shows that present (1976) municipal water usage including evaporation (about 18 Mgal/d) could be sustained during severe drought conditions with no additional sources required.

However, water needs are increasing each year in the area; in table 20 it can be seen that by the year 1985 water use in the City of Springfield is estimated to be 24.2 Mgal/d. This could pose a serious water-supply problem during times of severe drought if additional supplies are not provided.

Alternative Supplies

It is not the intent of this study to advocate any particular course of action that the City of Springfield should follow to obtain additional water supplies. Its purpose is to mention possible alternatives which should be considered.

As stated, the City of Springfield's estimated dependable supply may be exceeded by the year 1985, in which case an additional water supply would need to be provided. One alternative supply is the County Line Lake proposed by the U.S. Army Corps of Engineers. The lake would be formed by impounding the James River in the vicinity of the Webster-Greene County line. The County Line Lake would take

Table 19

DEPENDABILITY OF WATER SUPPLY FROM McDANIEL AND FELLOWS LAKES, WELLS, AND FULBRIGHT SPRING-2% CHANCE OF DEFICIENCY

1. Carryover storage analysis (methodology from Skelton, 1971)

    a. Drainage area contributing to lakes = 39.1 mi^2

    b. Maximum surface area of lakes = 300 + 820 = 1,120 acres

    c. Full-pool storage capacity of lakes (excluding storage allocated to siltation and conservation) = $8.5 \times 10^9 + 1.4 \times 10^9 = 9.9 \times 10^9$ gal = 30,380 acre-ft = 777 acre-ft/mi^2

    d. Evaporation loss = 1,120 acres X $\frac{42 \text{ in}}{12 \text{ in/ft}}$ X 0.75 = 2,940 acre-ft = 75 acre-ft/mi^2

    e. Storage capacity minus evaporation loss = 777 - 75 = 702 acre-ft/mi^2

    f. Runoff = 11.5 in/yr

    g. Maximum draft available (Skelton, 1971, fig. 3, p. 7) = 0.57 $ft^3/s/mi^2$ = 22.3 ft^3/s = 14.4 Mgal/d from lakes

2. Deep well production:

No. 1	1.0 Mgal/d
No's. 4-8	2.5 Mgal/d
No's. 10-12	2.7 Mgal/d
Total	6.2 Mgal/d

3. Fulbright Spring:

    Estimate 0.5 Mgal/d minimum flow

4. Capacity of present system:

    14.4 + 6.2 + 0.5 = 21.1 Mgal/d

Conclusion: During a severe, multi-year drought, a water supply of 21 Mgal/d could be obtained from existing sources with only a 2% chance of deficiency.

1/ "2% chance of deficiency" indicates that, on the average, the city water supply will be inadequate to sustain the indicated draft of 21.1 Mgal/d in 2 percent of the years (that is, 1 year in 50), and the reservoirs may become empty.

Table 20

PROJECTED WATER DEMANDS, CITY OF SPRINGFIELD
(from Burns & McDonnell, 1971)

Year	Average Day (Mgal/d)
1977	18.3
1980	19.9
1985	24.2
1990	28.5
1995	32.8
2000	37.1
2010	45.7
2020	54.3
2030	62.9

care of Springfield's water needs well past the year 2030's projected use of 62.9 Mgal/d (58 Mgal/d from County Line Lake, plus 21 Mgal/d from existing sources = 79 Mgal/d). Some of the arguments for and against the lake have been recorded in the "County Line Lake Missouri Draft Environmental Statement" (U.S. Army Corps of Engineers, July 1973). In this same report several other alternatives are mentioned such as importing water from Stockton Lake, and using ground water. However, the consequences of further development of the groundwater supply were not evaluated in the environmental impact statement.

An alternative apparently not considered is the possibility of artificially recharging the major aquifer when there is a surplus of surface water, and withdrawing water from the well when surface water is deficient. To determine whether artificial recharge would be possible in this area would require considerable study. A successful experiment in artificial recharge in which treated water was injected into a fissured carbonate rock aquifer overlying a sandstone aquifer in west St. Paul, Minn., was reported by Reeder and others (1976).

Another possible alternative might be utilization of some of the springs in the area. If springs were used it would, of course, be necessary to treat the water. Conjunctive use could be practiced as the City Utility does at Fulbright Spring. Water from the springs could be supplemented with water from deep wells when springflow was deficient. It might even be possible to

use treated spring water to artificially recharge the major aquifer.

Conjunctive use of surface and ground water could also be practiced by withdrawing water directly from the James River without benefit of impoundment and using a groundwater source during periods of drought. The surface water would have to be treated.

CONSEQUENCES OF DEVELOPING AN ADDITIONAL GROUNDWATER SUPPLY FROM THE MAJOR AQUIFER

It is probable that the amount of water withdrawn from the major aquifer will increase with time. Increased withdrawals from the major aquifer will of course be accompanied by a lowering of the potentiometric surface. Some of the problems that accompany lowering of the potentiometric surface are:

a. Increased pumping costs due to greater lifts.

b. Possible need to lower pumps within wells or even to deepen wells as might be the case with many domestic wells.

c. Possibility of inducing the flow of poorer quality water in areas where overlying aquifers may become contaminated.

The amount the potentiometric surface is lowered depends upon the amount of water withdrawn and on the hydrologic properties of the aquifer. Consequently, a digital simulation model was used to predict the effect that increased withdrawals from the major aquifer would have on the potentiometric surface of the major aquifer. Data collected during the course of this study furnished the input for the model.

SPRINGFIELD AQUIFER MODEL

A digital simulation model was used to predict the effect of increased pumpage from the deep aquifer on the potentiometric surface. The mathematical techniques and program used for the Springfield aquifer model are essentially the same as described by Pinder and Bredehoeft (1968). The area modeled includes all of Greene County, the northern one-third of Christian County, the western one-half of Webster County, and parts of other counties. The area is approximately 35 miles wide and 40 miles long. In the Springfield aquifer model, the nodes, or solution points, are concentrated in the metropolitan area where the nodes are spaced every one-half mile. The space between nodes increases away from the metropolitan area. In all, there are about 1,800 nodes in the model.

Both constant head and zero flow boundary conditions were used in various simulations. However, because of the rapid growth of the cone of depression, neither of these boundary conditions appeared appropriate. Specified gradient boundaries were not attempted because the change of the gradient of the potentiometric surface over time could not be predicted. Finally, a buffer zone approximately 200 miles wide was placed around the model and zero flow boundaries were assumed beyond the buffer zone. The aquifer properties in the buffer zone were assumed to be the same as the aquifer properties near the edge of the area modeled. Prior to the addition of this buffer zone, the results of a model simulation were unduly influenced by the choice of boundary conditions. However, after addition of the buffer zone, the choice of boundary conditions had no appreciable effect on the model results. The buffer zone is physically reasonable because the water-bearing formations extend a long distance in every direction.

The model was calibrated by programming change in pumpage and calculating the resulting change in water levels. The calculated change in water levels was compared with the observed change in water levels at selected sites.

The aquifer system in the Springfield area rapidly readjusts to any change in stress and a new equilibrium is soon established. Water levels can be expected to decline rapidly in response to additional pumpage, but after a few years these declines will no longer be significant (fig. 24). Because of this rapid response by the system, the exact history of pumping in the area did not need to be programmed into the model. Only the present figure for pumpage from the major aquifer was programmed (10.5 $feet^3/s$). This does not include the estimated rural domestic pumpage shown in table 18. Although this pumpage was assumed to have occurred continuously for the past 50 years, nearly identical results would have been ob-

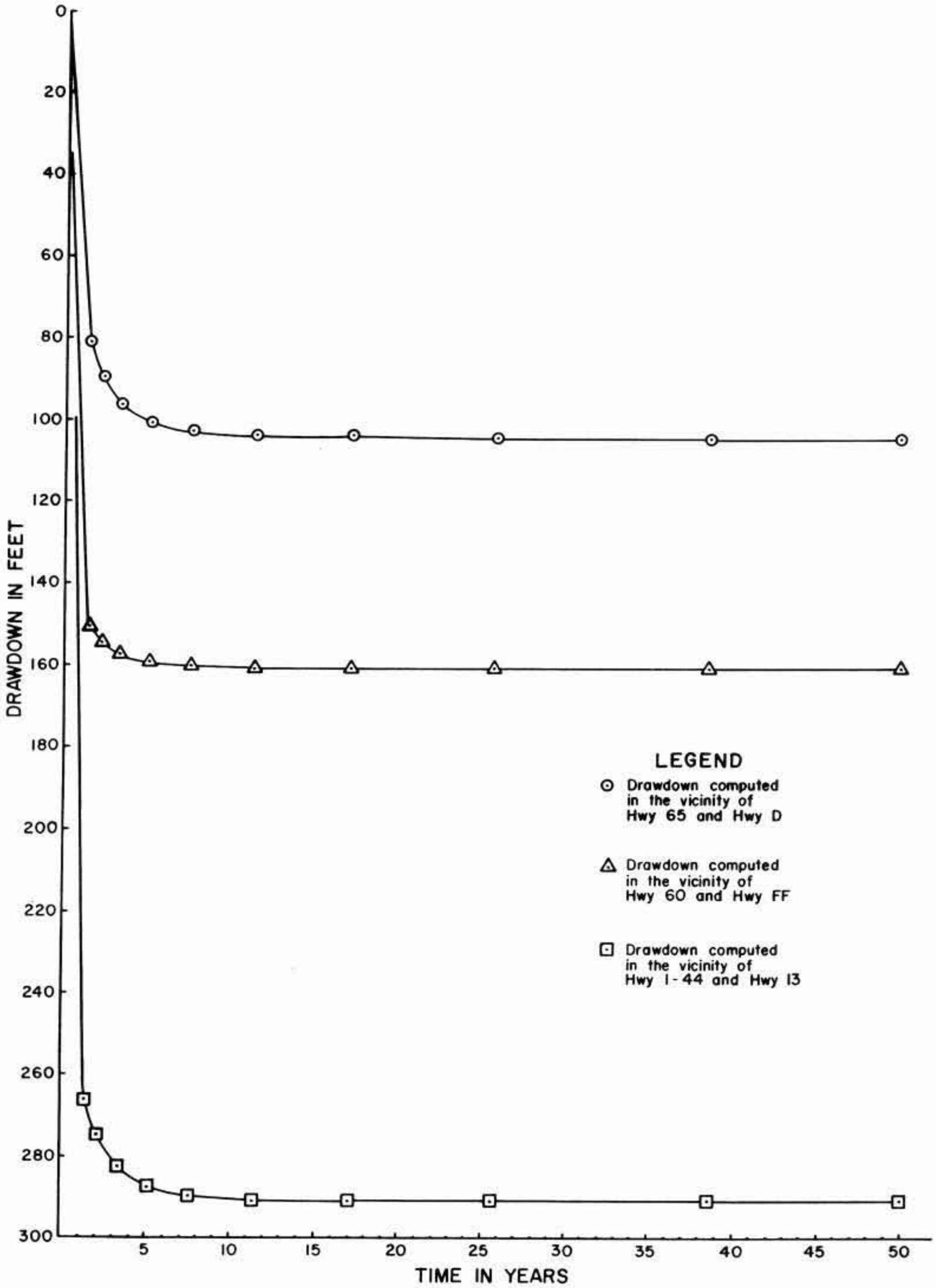


Figure 24

Computed hydrographs at selected points showing the relation between drawdown and time due to an additional 10 Mgal/d withdrawal from the major aquifer.

tained if the pumpage were assumed to have occurred for only the last 5 years.

The transmissivity of the major aquifer is estimated to be 670 $feet^2/d$ (as discussed previously in the section on "Aquifer Characteristics") and the storage coefficient is assumed to be equal to 0.0001, based on aquifer-test results. The thickness of the Northview Formation, which is assumed to be the dominant confining bed separating the major and minor aquifers, was determined from lithologic logs. The major parameter that was to be determined through model calibration was the vertical permeability of the Northview Formation.

The initial estimate for vertical permeability of the Northview Formation was $7.7X10^{-11}$ feet per second. This estimate was based on a value published by Walton (1960) for the vertical permeability of the Maquoketa Formation in northeastern Illinois. This formation is lithologically similar to the Northview Formation in the Springfield area. However, using this value of vertical permeability the calculated shape of the cone of depression is both too extensive and too deep. After several simulations, a new estimate of vertical permeability of $1.0X10^{-9}$ feet per second was made. Using this value of vertical permeability in a 50-year simulation, changes of approximately 150 feet were computed over the Springfield metropolitan area. In a few areas changes in excess of 200 feet were predicted. In this simulation the central part of the cone does not change appreciably after the first 5 years.

A comparison of observed water-level changes with computed changes at selected points where historical water-level data are available is given below:

Map Number (pl. 3)	Observed Change (feet)	Computed Change (feet)
38	120	190
39	100	150
45	200	183
49	180	196
52	170	190
70	199	203
84	179	192

The calibrated model was used to predict the effect of an additional withdrawal of 10 Mgal/d from existing wells in the Springfield area (fig. 25). The primary point of additional withdrawal was near McDaniel Lake, north of Springfield. The simulation was made for a 50-year period, but almost all of the water-level declines took place during the first 5 years of simulation. At the end of 50 years there was one node that declined 400 feet near Mc-

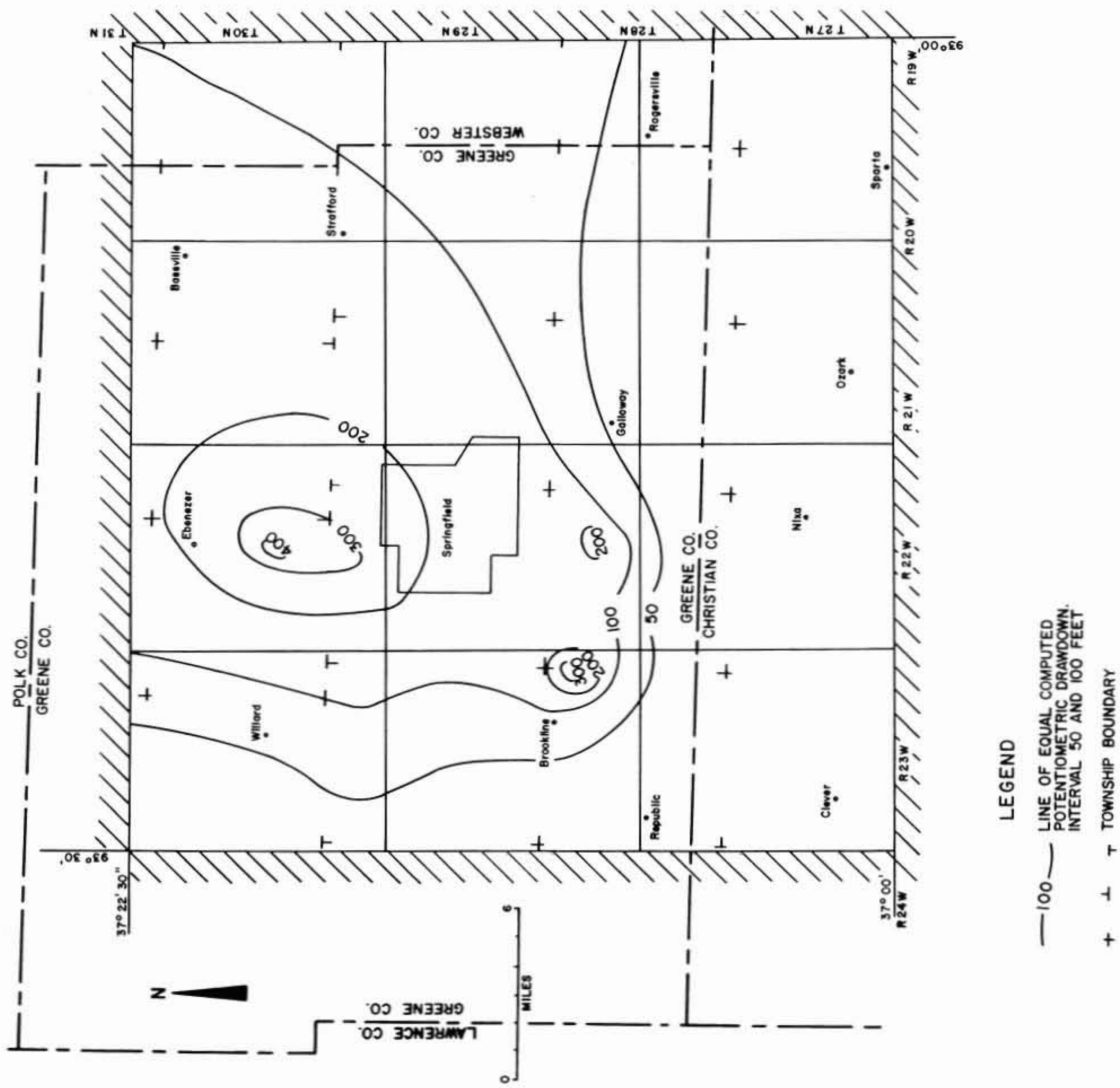


Figure 25

Computed drawdown in the major aquifer after 50 years of hypothetical pumping of an additional 10 Mgal/d.

Daniel Lake. About a dozen nodes experienced declines in excess of 300 feet, with a 200-foot decline area being quite large, north of Springfield. South of Springfield, there were two smaller areas that experienced a 200-foot decline. The 100-foot decline contour covered most of the Springfield area and much of the area northwest of Springfield.

As mentioned previously, the assumption was made that additional pumpage would not induce additional recharge to the major aquifer in the area where the major aquifer crops out. This assumption allowed the cone of depression to expand toward the outcrop area of the major aquifer in the northeastern part of the modeled area. In the buffer zone to the northeast of the modeled area, there are perennial streams which could conceivably be affected by additional withdrawal from the major aquifer. If these streams are affected, one of the assumptions of the model is violated and the projected water-level declines in the northeastern part of the area would be overestimated.

As can be seen from the foregoing explanation, the Springfield aquifer model is a very simplified approximation of the real system. To refine the model, it will be necessary to collect and analyze large amounts of additional hydrologic data.

CONCLUSIONS

The major aquifer in the Springfield area consists of over 1,000 feet of dolomite of Cambrian-Ordovician age. In much of the area this dolomite is overlain by as much as 300 feet of limestone (minor aquifer) of Mississippian age. At the base of the minor aquifer, the Northview Formation (a dolomitic siltstone, shale, and silty dolomite from 5 to 80 feet thick) acts as the upper confining layer for the major aquifer.

Differences in head favor the downward movement of water from the minor aquifer through the Northview Formation and into the major aquifer. The elevated Ca/Mg ratio of water from the

major aquifer also supports the idea of water moving down through the Northview Formation. Water from the minor (limestone) aquifer generally has a Ca/Mg ratio of greater than 5 to 1. Water from a dolomite aquifer should normally have a Ca/Mg ratio of about 1 to 1. In the Springfield area, however, the major (dolomite) aquifer has a Ca/Mg ratio of as high as 3 to 1, indicating a mixed water.

Individual wells in the major aquifer which are open to the stratigraphic sequence of Cotter Dolomite to Potosi Dolomite have yielded as much as 2,500 gallons per minute of good quality water with about 180 feet of drawdown in a 56-hour continuous pumping test. However, tests of short duration, because of their small sampling area and the inhomogeneity of the aquifer, do not reflect regional conditions. For example, using the closed-contour method of Lohman (1972) it was determined that the regional transmissivity of the major aquifer is about 670 $feet^2$ per day (5,000 gpd/ft).

Analysis of a digital model of the major aquifer indicates that additional water can be withdrawn from the aquifer. However, this will result in the additional lowering of the potentiometric surface. The severity of the lowering will depend on the amount of additional water to be withdrawn and also on the spacing of the wells. From the model study it was learned that withdrawal of an additional 10 Mgal/d from existing wells could result in a decline of the potentiometric surface of as much as 400 feet near the primary point of withdrawal.

A lowered potentiometric surface would result in increased pumping costs for wells within the affected area. A lowered potentiometric surface would also result in a need for lowering pumps within wells or even the need for drilling deeper wells.

The pervious nature of the karst terrane creates a potential for groundwater contamination. Because of this it is important that wells be properly cased and grouted to prevent surface contaminants from entering the aquifers. It is also extremely important to take into account the bedrock geology, soil conditions, and topography when determining the suitability of a site for a lagoon, landfill, artificial lake, or septic tank. Equally important could be consideration of the locations of losing reaches of streams.

Seepage runs made during the winter and spring on several streams in the area were instrumental in locating areas where streams lose water to bedrock. These streams (Pearson, Pickerel, and Terrell) sometimes have dry reaches during the summer and fall months. By making seepage runs during the winter and spring when there was continuous flow, it was not only possible to define the stream reaches where there were losses but, because of the saturated conditions, to prove conclusively that losses were to underlying bedrock and not just to alluvial fill.

Analyses of data collected at water-quality monitoring sites on Wilson Creek and James River showed that the quality of the initial flush of storm run-

off following several weeks of stable weather conditions was poor. However, the quality of storm runoff improved dramatically after the first few hours of flooding. Upstream from the sewage-treatment plant on Wilson Creek, storm runoff could be successfully stored for later use after a few hours of flooding. Computations of maximum draft rates from existing surface-storage reservoirs, wells, and springs during a severe, multi-year drought show that a water supply of 21 Mgal/d could be obtained from these sources with only a 2-percent chance of deficiency. However, if projected demands are accurate, a serious water-supply problem could develop by 1985 during times of severe drought unless additional supplies are provided.

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Appendix 1

DEFINITIONS OF TERMS

Aquifer - A formation, group of formations or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Artesian Water - Ground water under sufficient pressure to rise above the level at which the water-bearing bed is reached in a well. Ground water under artesian pressure is also called confined water.

Base Flow - Sustained or fair-weather flow.

Confining Bed - A body of relatively impermeable material stratigraphically adjacent to one or more aquifers.

Continuous-Record Station - A site on a stream where continuous records of discharge are obtained.

Cubic Feet Per Second (ft^3/s) - The unit expressing rate of discharge. One $foot^3/s$ is the rate of discharge of a stream having a cross-sectional area of 1 square foot (ft^2) and an average velocity of 1 foot per second.

1 ft^3/s = 7.48 U.S. gallons per second (gal/s)

= 449 U.S. gallons per minute (gal/min)

= 0.646 million of U.S. gallons per day (gal/d)

Dolomite - A term applied to rocks that approximate the mineral dolomite ($CaMg[CO_3]_2$) in composition.

Evapotranspiration - The movement of water into the atmosphere by the combined processes of direct evaporation and transpiration by plants.

Fault - A fracture or fracture zone in rocks along which there has been displacement of the two sides relative to one another, in the plane of the fracture.

Graben - A long narrow depressed area bounded by faults.

Hydrology - The science that relates to the water of the earth.

Interrupted Stream - A stream which contains alternating reaches that are either perennial, intermittent, or ephemeral.

Low Flow - The portion of stream discharge that is derived primarily from ground-water outflow.

Partial-Record Station - A site on a stream where occasional discharge measurements have been collected over a period of years.

Perennial Stream - A stream that flows continuously throughout its reach.

Permeability - A measure of the relative ease with which a porous medium can transmit a liquid under a potential gradient.

Potentiometric Surface - A surface which represents the static head. As related to an aquifer it is defined by the levels to which water will rise in tightly cased wells.

Recharge - The addition of water to the zone of saturation. Infiltration of precipitation is a form of natural recharge.

Recurrence Interval - The average interval of time within which a given event will be exceeded once. Recurrence intervals are averages and do not imply regularity of occurrence; an event of 50-year recurrence interval might be exceeded in consecutive years or it might not be exceeded in a 100-year period. In other words, a 50-year drought or flood has a 2-percent chance of occurrence in any year.

Seepage Run - A series of discharge measurements made in a short time identify stream reaches where gains or losses in flow occur.

7-Day Q_2 - The annual minimum average discharge for 7 consecutive days that will occur on an average of once in 2 years. This is an index to the low-flow potential of a stream and can be used as a guide in comparing one stream to another.

Soil Infiltration Index - This value is the maximum potential difference, in inches, between storm rainfall and storm runoff. It is dependent on soil-water storage and infiltration rates of a watershed.

Specific Capacity - The rate of discharge of water from a well divided by the drawdown of water level in the well. If a well yields 500 gpm (gallons per minute) with a drawdown of 25 feet, its specific capacity is 500/25 or 20 gpm per foot of drawdown.

Specific Conductance - A measure of the capacity of water to conduct a current of electricity, expressed in micromhos per centimeter (umhos/cm) at 25°C (degrees Celsius). Conductance varies with the quantities of dissolved mineral constituents and with the degree of ionization of the constituents as well as with the temperature of the water. It is useful in indicating the approximate concentration of mineral matter in water.

Standard Error of Estimate - A measure of the reliability of a regression. It is the standard deviation of the distribution (assumed normal) of residuals about the regression line.

Storage Coefficient - The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.

Transmissivity - The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient.

Transpiration - The process by which water vapor escapes from a living plant and enters the atmosphere.

Unconformity - A surface of erosion or nondeposition that separates younger strata from older rocks.

Water Table - That surface in an unconfined water body at which the pressure is atmospheric.

Appendix 2

CONVERSION FACTORS

The English units used in this report can be converted to metric units by multiplying the factors given in the following list:

English Unit To Convert	Multiply By	Metric Unit To Obtain
Acres	0.4047	Hectares (ha)
	4.047×10^{-3}	Square kilometer (km^2)
Acre-feet	1.233×10^{-3}	Cubic hectometers (hm^2)
Cubic feet per second (ft^3/s)	2.832×10^{-2}	Cubic meters per second (m^3/s)
	0.2832	Liters per second (L/s)
Feet (ft)	0.3048	Meters (m)
Feet per day (ft/day)	0.3048	Meters per day (m/day)
Square feet per day (ft^2/day)	0.0929	Square meters per day (m^2/day)
Gallons per minute (gal/min)	6.309×10^{-2}	Liters per second (L/s)
Inches (in)	25.4	Millimeters (mm)
Miles (mi)	1.609	Kilometers (km)
Square miles (mi^2)	2.59	Square kilometers (km^2)

Section 2

AREAL GEOLOGY

By *Thomas L. Thompson

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DISCUSSION OF FORMATIONS

Those rock formations cropping out in the Springfield area are illustrated on plate 2. Descriptions of these units can also be found in Beveridge (1970), Fellows (1970), and Thompson and Fellows (1970), all of which include stratigraphic descriptions in Greene County. The following discussion begins with the oldest (lowest) formation first.

ORDOVICIAN SYSTEM
CANADIAN SERIES
Cotter Dolomite

The Cotter Dolomite is a brown to buff, earthy dolomite, containing scattered beds and bands of chert and quartz sandstone. In the lower part of the Cotter, a thick sandstone (the "Swan Creek" sandstone) is exposed in the vicinity of Northview, Webster County (just east of the map area).

MISSISSIPIAN SYSTEM
KINDERHOOKIAN SERIES
Bachelor Formation

The Bachelor Formation marks the base of the Mississippian System and is a distinctive stratigraphic unit in spite of its thinness. It consists of two lithologies, a basal green quartzose sandstone and an upper greenish shale. The lower sandstone usually contains fragments of chert reworked from older strata, and phosphatic nodules and debris (fish teeth). It is characterized by a calcareous cement that is in optical continuity (a "glint" cement), and has yielded a profuse fauna of distinctive microfossils (Thompson and Fellows, 1970). The upper shale is calcareous and usually sandy.

Both units of the Bachelor Formation are extremely widespread. They average only 3–4 inches each in thickness, although the lower sandstone may vary considerably due to the unevenness of the surface upon which it was deposited (from 2–6 inches in some exposures). The basal contact of the sandstone with the underlying formation may be "welded", that is, the two units seem to merge one to another without any appreciable break. However, this contact often represents an erosional period of several hundred million years duration. The upper contact of the Bachelor Formation is sharp and distinct.

Compton Formation

The Compton Formation is usually a light-gray limestone composed of a finely crystalline matrix cementing small fossil fragments (crinoid ossicles together). In northern Greene

County, this formation has been partially dolomitized to a brown to tan, earthy dolomite, strongly resembling the Cotter Dolomite (Ordovician in age). However, the scattered crinoid ossicles were not destroyed, and impart a peppery appearance to the Compton, distinguishing it from the Cotter Dolomite.

The Compton Formation averages 10-15 feet in thickness, and has a sharp basal contact with the Bachelor Formation. The upper contact, however, is often transitional with the silty dolomite of the overlying Northview Formation, so that a sharp or distinct break is usually not present.

Northview Formation

Within the region shown on the map, the Northview Formation is extremely variable in nature. It ranges from 5 feet in thickness in the extreme southern part of Greene County to 80 feet in the northern part of the County. Where the Northview is thickest, the lower part is primarily a dolomitic siltstone and shale, and the upper part is a silty dolomite. Several prominent siltstone beds are present in the upper half of the Northview. In the southern part of the county, the thinner Northview is primarily a silty shale and is usually greenish-gray in color. Particularly characteristic of the Northview Formation are surface markings on the siltstone beds that resemble fans or rooster tails, termed "caudagalli".

OSAGEAN SERIES

Pierson Formation

The Pierson Formation was named from exposures on Pierson Creek, just east of Springfield. Here it consists of silty dolomite in the lower part, grading upward into dolomitic cherty limestone. South from Springfield, the Pierson becomes less and less dolomitic, changing facies to a light-greenish-gray, medium-crystalline, fossiliferous limestone in Christian County. To the north it thins and also becomes less dolomitic. In Greene County, the Pierson Formation averages 40 feet in thickness.

Although it represents a series boundary, the lower boundary of the Pierson Formation, with the Northview, is often difficult to locate exactly. This is because the bluish, silty dolomite of the Northview has often been reworked with and incorporated into the brown dolomite of the basal Pierson. The upper boundary with the Elsey Formation is very transitional and is based on an increase in chert percentage to around 50 percent by volume, along with a change of the carbonate to a purer calcium carbonate (little or no dolomite).

Elsey Formation

The Elsey Formation is finely crystalline, gray, fossiliferous limestone interbedded with light-gray, mottled, spicular chert that occurs as nodular beds and discontinuous beds of nodules. The limestone:chert ratio is about 50:50. The limestone beds are 6 inches to 2 feet in thickness and the chert nodules

are 3 inches to 1 foot. Weathering produces limestone beds with a nodular, rounded appearance. Crinoid ossicles are scattered throughout both the limestone and chert, and lenses of medium- to coarsely-crystalline crinoidal limestone are common. The Elsey Formation averages 50 to 60 feet in thickness in Greene County, but can be thicker. Its boundaries are transitional both with the Pierson below and the Burlington limestone above.

Burlington and Keokuk Limestones, undivided

The Burlington and Keokuk Limestones represent about 150 feet of light-gray, coarsely-crystalline, crinoidal limestone. Chert is present in zones that are 15 to 20 feet apart, with relatively pure calcium carbonate in between. The sequence is very coarsely-crystalline (essentially composed of crinoid ossicles) in the lower part (Burlington Limestone) and gradually decreases in grain size upward to a fine- to medium-crystalline, fossiliferous limestone at the top (Keokuk Limestone). This transition is so gradual that no formational boundary can be recognized in the mapped region. The chert is like that of the Elsey--white to gray, mottled, spicular, as nodules and discontinuous beds.

The top of the Keokuk Limestone is identified by the Short Creek Oolite Member, a 4- to 6-foot bed of essentially pure carbonate ooids averaging 1 millimeter in diameter. The top of the Short Creek has been defined as the top of the Keokuk Limestone, the top of the Osagean Series.

MERAMECIAN SERIES

Warsaw Formation

Above the Short Creek Oolite Member of the Keokuk Limestone are a few feet of light-gray, medium-crystalline limestone, very similar in lithology to the upper part of the Keokuk Limestone immediately beneath the Short Creek. This limestone is the basal part of the Warsaw Formation, a unit that is better represented in the vicinity of Joplin, Mo., west of the mapped area.

PENNSYLVANIAN SYSTEM

Throughout the western part of the mapped area are scattered outcrops of sandstone that are considered to represent the Pennsylvanian System. These are usually of very local distribution, and are very difficult to map. Areas shown on the map do not necessarily represent a blanket deposit, but may be regions of scattered small sandstone exposures. Many more sand outcrops are present in the western part of the mapped region, but not enough information is known about their distribution to warrant inclusion on the map.

ACKNOWLEDGMENTS

The Greene County region mapped consists of a composite of 12 $7\frac{1}{2}$ minute quadrangles. All but two of these quadrangles have been previously mapped in at least reconnaissance detail. The following list acknowledges those people responsible, at least in part, for the geologic mapping of these 12 quadrangles.

Quadrangle	Contributor
Bassville	T. R. Beveridge
Brookline	R. Walker
Ebenezer	R. Walker and T. L. Thompson
Galloway	L. D. Fellows
Nixa	T. L. Thompson
Oak Grove Heights	W. C. Hayes and T. L. Thompson
Ozark	W. C. Hayes
Republic	R. Walker and T. L. Thompson
Rogersville	T. L. Thompson
Springfield	L. D. Fellows
Strafford	J. Pulliam
Willard	R. Walker

Section 3

ENGINEERING GEOLOGY

By *John W. Whitfield

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Table 21

PROBLEMS IN URBAN DEVELOPMENT

Unit	Lakes	Lagoons	Landfills	Streams
Ul	Slight for small lakes. Excavation should not penetrate hardpan.	Slight. Excavation should not penetrate hardpan.	Severe. Soil above hardpan not thick enough for landfill. Excavation through hardpan would expose permeable cherty red clay.	Wet weather stream, usually gaining.
Ur	Severe. Permeable soil & bedrock conditions. Small lakes can sometimes be built if clay is treated with chemicals.	Severe. Remedial treatment with chemicals or a compacted clay liner usually needed to prevent leakage.	Severe. Moderate. Permeable soil and bedrock.	Usually losing.
Uc	Moderate for small lakes. Severe for large lakes.	Moderate for no discharge lagoon. Severe for discharging lagoon if located in sink.	Severe. Permeable soil and bedrock.	Usually losing.
Va	Slight for small lakes. Moderate to severe for large lakes.	Moderate. Limited by by soil thickness, and losing reaches of streams.	Severe. Limited by soil thickness and size of valleys, and shallow groundwater table.	Gaining, may have losing reaches.
Vb	Severe. Permeable soil and bedrock. Small lakes can sometimes be built on slopes.	Severe. Permeable soil and losing stream.	Severe.	Losing.
Vc	Slight.	Slight.	Slight. Best locations on terraces; limited by depth to ground water and flooding.	Gaining.
Sr	Slight. Best sites at foot of slopes.	Slight. Limited by slopes.	Slight. Limited by slopes.	Gaining.
Sa	Moderate to severe. Bedrock in slopes can be severely weathered. Bedrock may contain open joints and bedding planes through which lake water could leak.	Severe. Limited by slopes and thin soil cover over bedrock.	Severe. Limited by slopes and thin soil cover over bedrock.	Wet weather stream, usually gaining.
Urs	Slight to moderate. Soil may be permeable due to high sand content. Bedrock may contain open bedding planes through which lake water could leak.	Moderate. Padding may be needed over permeable soil.	Severe. Limited by soil permeability and soil thickness.	Wet weather stream, usually gaining.
Urb	Slight. Upper part of bedrock may contain open bedding planes and joints.	Slight.	Slight. Limited by thin soil cover.	Gaining.

Table 21 (continued).....

Unit	Septic tanks	Slope stability	Slab foundations	Footings	Excavation
Ul	Moderate. Hardpan will impede downward movement of effluent. Effluent will surface during wet periods.	Slight.	Slight.	Slight.	Slight.
Ur	Severe. Rapid downward percolation of effluent, very little dilution.	Slight.	Moderate.	Severe. Bedrock surface variable due to weathering. Bedrock can contain open joints.	Severe. Bedrock pinnacles can hamper excavation.
Uc	Moderate to severe in upper silty clay. Can have rapid percolation in red cherty clay beneath upper silty clay.	Slight.	Moderate. Could be some swelling in upper silty clay.	Severe. Pinnacle bedrock surface. Large voids can be beneath surface of valley sides and floors.	Severe.
Va	Severe on slopes. Slight in valleys.	Slight.	Slight. Limited by sides of valleys.	Moderate. Limited by sides of valleys and ground water flowing into footing excavations.	Severe. Shallow bedrock and ground water.
Vb	Severe. Rapid percolation through permeable soil and bedrock.	Slight.	Moderate. Limited by sides of valley flash flooding.	Severe. Limited by sides of valleys and irregular rock surfaces.	Slight to severe. Irregular below rock surface.
Vc	Slight.	Slight.	Slight.	Moderate. Limited by water table. Unit is in a floodplain; flooding could occur.	Moderate. Limited by water table. Unit is in floodplain; flooding could occur.
Sr	Slight. Shale impedes downward movement of effluent. Effluent may surface on slopes.	Moderate. Slides can occur in fill material placed on top of unit.	Severe. Swelling of residual soil. Foundation limited by slopes.	Severe. Swelling of residual soil. Slopes will make construction difficult.	Slight in shale. Severe in siltstone. Slopes may impede excavation equipment.
Sa	Severe. Very little soil cover on steep slopes.	Slight.	Severe. Steep slopes.	Severe. Weathered bedrock can contain open joints and bedding plains.	Severe. Slopes will impede excavation equipment. Thin soil cover over bedrock.
Urs	Moderate. Thin soil cover over bedrock.	Slight.	Slight.	Slight. Bedrock surface may be uneven.	Slight to severe. Irregular bedrock surface.
Urd	Slight. Tight residual clay will slow downward percolation of effluent.	Slight.	Severe. Swelling in residual clay.	Slight.	Slight to severe. Irregular bedrock surface.

Table 22

DESCRIPTION AND CHARACTERISTICS OF MAP UNITS

Units	Bedrock Characteristics	Soil Characteristics	Soil Thickness (feet)	Topography	Groundwater	Drainage		Remarks
						Surface	Internal	
Ul	Massive limestone 100'-200' thick, very cherty in places, weathers to an irregular surface. Contains numerous caves and solution openings.	Upper soil - clayey silt to silty clay, low permeability, contains hardpan. Lower soil-red cherty clay, breaks down to blocky structure with slickensided surface.	2-5 1-30	Flat to gently rolling.	May be local; perched water on top of hardpan.	Slow to moderate.	Slow in upper soil. Moderate to rapid in lower soil.	
Ur	Same as Ul; in addition, unit Ur contains numerous sinkholes on land surface as a result of severly weathered bedrock.	Red cherty clay, breaks down to blocky structure with slickensided surfaces.	1-30	Gentle to rolling; large karst areas.	In bedrock; moves through open joints and bedding planes in bedrock.	Rapid.	Rapid.	Many losing streams.
Uc	Same as Ul.	Upper soil - colluvial silty clay. Lower soil - red cherty clay.	1-10 1-30	Upland valleys, sinkholes.	In bedrock.	Moderate to rapid.	Slow to moderate in upper soil. Moderate to rapid in lower soil.	
Va	Limestone, shale, and dolomite.	Stratified clay, sand, and gravel.	3-10 in upper watershed 0-10 in lower watershed.	Secondary valleys, sides of valleys become rocky in lower parts of valleys.	0-10 feet; numerous springs in this unit.	Moderate to rapid.	Rapid in sand and gravel; slow in clay.	Streams may have alternate losing and gaining reaches.
Vb	Mostly weathered limestone. Bedrock conditions similar to those in Unit Ul.	Mixture of colluvial and alluvial boulders, gravel, and some small amounts of clay. Very little stratification of soil. Floor of stream covered by poorly sorted deposits of boulders and gravel.	0-10	Secondary valleys. Stream channels poorly defined.	In bedrock.	Rapid.	Rapid.	Many losing streams.
Vc	Limestone and dolomite.	Alluvial deposits of soil in valley bottom. Colluvial clays on valley slopes.	5-30	Major valley, steep slopes, wide floodplains.	5-15 feet below land surface.	Slow on flat floodplain.	Slow to moderate.	
Sr	Shale and siltstone.	Silty clay derived from weathered shale.	3-8	Slopes.	Springs can occur on top of this unit.	Rapid.	Slow.	Slides can occur in fill soils placed on top of this unit.
Urs	Sandstone.	Mixtures of sandy clay, sand, and sandstone boulders; derived from weathered sandstone.	0-5	Rolling.	May contain small amounts of groundwater locally.	Moderate.	Slow to rapid, depending on clay content of soil.	
Urd	Dolomite.	Residual cherty silty clay.	0-10	Rolling.	Dolomite beds contain sandstone which yields groundwater locally.	Moderate to rapid.	Slow.	
Sa	Limestone and dolomite.	Gravelly silty clay. Slopes generally have small amounts of soil cover.	0-5	Rugged slopes.	Numerous wet weather springs on slopes. Scattered springs that flow the entire year.	Rapid.	If bedrock is badly weathered, internal drainage can be rapid.	

INTRODUCTION

Urban development may cause problems with lagoons, lakes, landfills, septic tanks, etc. if the geology and engineering properties of soils and bedrock are not considered. Plate 4, "Engineering Geology Map of the Springfield, Missouri Area" depicts the engineering geology of the study area and tables 21 and 22 and the text describe the topographic settings, soils, bedrock, etc.

Ten units represent engineering geologic conditions in this report. Factors used in delineating these units include soil types, bedrock conditions, and topographic positions, all of which must be considered. At the inception of this study, several other methods were considered for forming engineering geologic units, but they were not found to be practical because soil types, bedrock conditions, and topographic positions have such profound effects on engineering geologic conditions.

Effects of each of these units on lakes, lagoons, landfills, and streams are discussed and a tabulation sheet at the end of the report gives a brief summary of the engineering behavior of each unit.

UNIT Ul

Uplands; loessial soil over residual soil (fig. 26).

TOPOGRAPHIC SETTING: Broad, flat to slightly rolling upland.

UNIT THICKNESS: 2-5 feet

SOIL: The presence of the loess (Unit Ul) introduces a different set of soil engineering characteristics than in Unit Ur. Unit Ul is composed of wind-deposited clayey silt and silty clay, 2 to 5 feet thick. Unit Ul rests on top of Unit Ur which is composed of residual soil developed from weathered limestone.

Soil in Unit Ul is usually a brown to dark brown color. On the flat uplands, Unit Ul contains a dense hardpan layer, 18 to 36 inches beneath the surface. This hardpan is generally less than a foot thick and has low permeability.

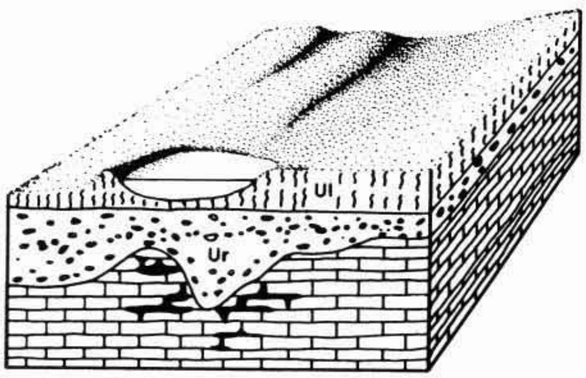

Figure 26
Unit Ul, uplands with loessial soil over residual soil.

BEDROCK: Very seldom does Unit Ul lie directly on top of bedrock; instead, Unit Ul rests on Unit Ur. Bedrock beneath the soil units consists of weathered limestone that contains large solution enlarged joints and bedding planes. Numerous caves are in the limestone. The bedrock surface can be highly irregular (pinnacled) due to weathering.

KARST AREAS: This unit contains karst areas although not as pronounced as in Unit Ur. Sinks are generally isolated.

ENGINEERING GEOLOGY: The loessial soil has low permeability and is suitable for small ponds and sewage lagoons. When the loess soil layer (Unit Ul) is removed and the underlying residual red stoney soil (Unit Ur) is exposed, there may be leakage in the stoney soil.

Wet spots or marsh-like areas will often occur on the surface of Unit Ul during the winter and spring months. Because of the flat topography and the presence of a hardpan, surface water drains slowly from the Ul surface. Wet areas can hamper farming operations or accessibility to construction projects.

An inflow of seep water can be expected in excavations for utility trenches, foundations, and basements. The hardpan has a low permeability and infiltrating surface water collects on top of the hardpan, forming a seasonally-perched water table. When excavations intersect the hardpan, perched water flows into the excavation. The water usually flows into a trench for a day or so before stopping. Flow will start up again after rainfall, however. The amount of flow is small, but troublesome, and a pump is usually needed to drain excavations. Basements need drains at footing levels around outside walls.

LAKES: Large lake sites are limited in Unit Ul. The land surface is rather flat and lacks well defined valleys which would be suitable for constructing large lakes.

There are small lake sites in the small, upland valleys situated around the periphery of the flat uplands.

One of the problems with constructing lakes in Unit Ul is that the brown loessial soil is usually stripped from the bottoms and sides of the valleys to make larger lake basins. When the clayey soil of Unit Ul is removed, then large expanses of permeable red stoney soil (Unit Ur) are generally exposed in the lake basins.

To prevent leakage, this red stoney soil should be treated with soda ash or covered with a clay pad. Both sealing methods are costly and success is uncertain.

Small ponds can be constructed in Unit Ul. If at all possible, the pond floor should not penetrate the brown loessial soil. If Unit Ul is thin and it is necessary to expose the underlying red stoney soil in the pond floor then a pad of some sort will be needed to prevent leakage. A compacted clay pad consisting of a half-and-half mixture of brown clay from Unit Ul and red stoney soil can be used. Sometimes the red stoney soil can be sealed by applying a little soda ash (1 pound per 5 square feet) and then disking and compacting the surface of the treated clay.

LAGOONS: This unit is favorable for lagoons. Excavations should be kept to a minimum so that the underlying red stoney soil is not exposed. If the red stoney soil is exposed, remedial treatment will be necessary. If only small areas of red stoney soil are exposed inside the lagoons, the stoney soil can be over-excavated to a depth of 24 inches and replaced with compacted brown clay.

Deep excavations for lagoons require more costly sealing methods to prevent leakage. Remedial treatment can range from a water-tight rubber or plastic liner to a compacted, chemically treated clay pad.

Pinnacled bedrock and voids may be encountered in deep excavations.

Intersector trenches may be needed around the outsides of lagoon excavations to intercept flow from perched water tables.

LANDFILLS: Unit Ul is not favorable for landfills because soils vary in thickness and are generally not thick enough to provide a water-tight base and cover material for landfills.

RECEIVING STREAMS: Receiving streams in this unit are dry most of the year. They are located in the upper reaches of watersheds and do not receive enough surface runoff or recharge from groundwater supplies to maintain a year-round flow.

Small wet weather springs occur in shallow gulleys in the uplands. Early-day farmers valued these small springs as water sources for their families and livestock. Shallow basins made of stone were built at the spring orifices to hold water. Many of these spring orifices are marked by large sycamore trees growing nearby.

UNIT Ur

Uplands with residual soil over weathered limestone (fig. 27).

TOPOGRAPHIC SETTING: Flat to rolling uplands with gentle to moderate

slopes where Unit Ur grades into Unit Sa. Large karst areas; sinkholes, caves, and springs are common. Because of the weathering characteristics of the Burlington Limestone, bedrock pinnacles and residual chert boulders are common.

UNIT THICKNESS: 1-30 feet

SOIL: Soil developed as a residuum from the weathering of the underlying cherty limestone. Soil mantle ranges from red colored clayey soil to layers of chert boulders and gravel containing very little clay. The chert boulders and gravel are formed from the breakdown of chert weathered from the limestone. After the soluble carbonate portion of the limestone has been altered to residual soil the more resistant chert is left "floating" in soil. Layers of residual chert will often retain bedding characteristics of the bedrock, forming undulating horizontal beds of chert situated between soil layers.

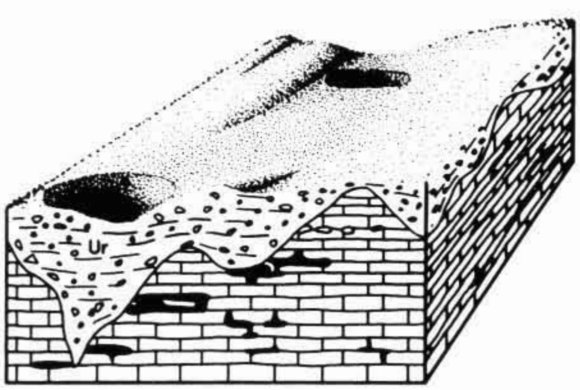

Figure 27
Unit Ur, uplands with residual soil over weathered limestone.

In some places, soil sequences in Unit Ur may be over 10 feet thick and contain very little chert. In other places there will be sequences of chert boulders and gravel layers 1 to 4 feet thick, separated by a thin layer of clay.

KARST AREAS: The subsurface soil and bedrock in Unit Ur contain caves, pinnacles, and solution enlarged joints. Chemical weathering of bedrock by infiltrating surface water has formed a network of underground openings.

Sinkholes have formed in the area when the soil roofs of underground openings have gradually weakened and collapsed to form sinkholes on the land surface. Widely scattered sinkholes are present over the entire unit. There are also areas where clusters of sinks occur, indicating intense karst activity in the bedrock. Examples of these clusters occur near Sparta, Nixa, and the Springfield Municipal Airport.

BEDROCK: Massive cherty limestone which contains large solution enlarged joints and bedding planes. Caves in limestone are numerous. The bedrock surface in this unit can be highly variable due to the pinnacled surface produced by weathering.

ENGINEERING GEOLOGY: The engineering geology of the unit is affected by several factors:

a. <u>Weathering of soil and bedrock in karst areas</u>: The effects of weathering on soil and bedrock in karst areas cannot be ignored in planning for future developments. Catastrophic collapse can

occur beneath lakes and lagoons. Homes situated in sinkholes which have been leveled or filled can be flooded by slowly draining surface water. Excavations for foundation footings can encounter a pinnacled uneven bedrock surface and solution enlarged openings in the bedrock.

Development in karst areas can be done but unusual engineering problems and expensive remedial treatment should be expected.

Karst areas have underground drainage systems connected by networks of various sized openings. Liquid pollutants from lagoons, treatment plants, and landfills that enter the networks of underground openings can spread rapidly and contaminate groundwater in the karst bedrock and affect springs and water wells.

b. Engineering features of soil: Blocky structure and light density. Much of the residual clay in this unit has a blocky structure that is caused by the iron element in the soil acting as a binding agent between clay particles. The cracks between small blocks of clay increase the permeability of the soil and decrease soil density. When the clay dries or is exposed to air, it breaks down into blocky sand-size pieces. In this state the clay behaves more like a silt or sand than a clay.

c. Chert residuum in soil: The large amount of chert gravel and boulders in the soil increases permeability. A layer of chert gravel or a relict chert bed that has numerous fractures can be an avenue for rapid lateral movement of water.

LAKES: This unit is not favorable for lakes due to the permeable nature of the soil and bedrock, and the possibility of a sink or cave collapse in the lake basin. The cost of compensating for soil and bedrock conditions would make most lakes too expensive to build.

Small ponds of 1 acre or less can be made to hold water if the soil exposed in the pond basin is compacted by a sheeps foot or rubber tired roller. Clay should be very moist when compacted. Gravel and chert beds exposed inside the pond basin should be removed and replaced by clayey soil.

There has been some success in sealing leaking ponds in the residual soil (Unit Ur) by treating the soil with chemicals such as soda ash or trisodium polyphosphate. The chemical breaks down the blocky structure of the soil and destroys the small cracks between the blocks. It should be spread over the red soil at the rate of 1 pound per 5 square feet of surface area; the surface is then disked and compacted.

Ponds in this unit often behave differently in their ability to hold water. One pond may be dry while a hundred yards away another pond may hold water, possibly because of the manner in which the ponds were constructed. Soil in the basin of a pond holding water may have been disked and compacted.

LAGOONS: To prevent leakage in lagoons, it may be necessary to chemically treat soil in the lagoon floors and sides or, if the soil contains large amounts of gravel, the lagoons can be lined with a clay blanket or plastic liner.

Deep excavations for lagoons may encounter numerous permeable chert layers and/or bedrock pinnacles resulting in expensive sealing costs.

LANDFILLS: Unit Ur is not favorable for landfills, especially in karst areas, because of permeable soil and bedrock. There are exceptions though such as the hilltops overlooking the Eureka Springs Escarpment in northern Greene County, where it is possible to develop suitable landfills. These hilltops are underlain by a 40-foot (or thicker) layer of Northview Shale. The downward migration of landfill leachates is blocked by this relatively impermeable shale. Leachates move along the top of the shale and emerge on the hillsides where it can be captured by conduit trenches and directed to lagoons. Landfills located on the hilltops require careful planning. Some of these areas are not practical to use because of the rugged terrain.

Other possible landfill sites in Unit Ur would be where the residual soils are more than 35 feet thick. A testing and drilling program would be needed on these sites to determine soil permeability at various depths, presence of caves, depth to ground water, and direction of groundwater movement. Engineering plans should provide for leachate drains in bottoms of landfill trenches so that the leachates can drain laterally to lagoons on the surface.

RECEIVING STREAMS: Streams in Unit Ur are in two categories:

a. Wet weather streams: Dry most of the year, and flow only during wet periods. These streams are usually near the crest of the watershed.

b. Losing streams: Lose their flow into the underlying permeable bedrock or soil. Thus pollutants entering losing streams can also enter openings in the bedrock that lead to caves or passageways which may extend for miles. Once in these passages, liquid waste may travel long distances contaminating the ground water it comes in contact with.

Most losing streams (which may be located in any segment of the watershed) are tributaries to streams in Unit Vb.

UNIT Uc

Upland valleys with colluvial soil over residual soil (fig. 28).

TOPOGRAPHIC SETTING: Upland valleys with gentle sloping sides. Valleys have several different shapes which appear to be influenced by weathering of the underlying bedrock and flat topography. Some valleys are bowl shaped while others are long, narrow, channel-like valleys. Sides of the valleys range from gently sloping to almost flat.

THICKNESS: 1-10 feet on valley floors
1-3 feet on valley floors

SOIL: Mixtures of gravel, silt, and clay constitute the soil which is washed down from the surrounding uplands. In places, this soil is very silty or contains a high percentage of chert gravel.

The silty clay soil has medium to low permeability.

Although Unit Uc generally rests on Unit Ur, which is 1 to 30 feet thick, there are some valley bottoms where Unit Uc rests directly on bedrock.

BEDROCK: The bedrock is weathered limestone with large solution enlarged joints and bedding planes. Caves may be present. The bedrock surface may be highly variable where weathering has produced a pinnacled surface.

KARST AREAS: Many of the valleys and basins where Unit Uc is found are old sinkholes. These valleys and basins are generally circular in shape, but some have elongated, channel-like shapes with gently sloping sides. These may reflect solution-enlarged joints in the underlying bedrock or may be the result of a combination of flat topography and the slow erosion of uniformly textured soil, (Secs. 5 and 6, T. 29 N., R. 21 W.

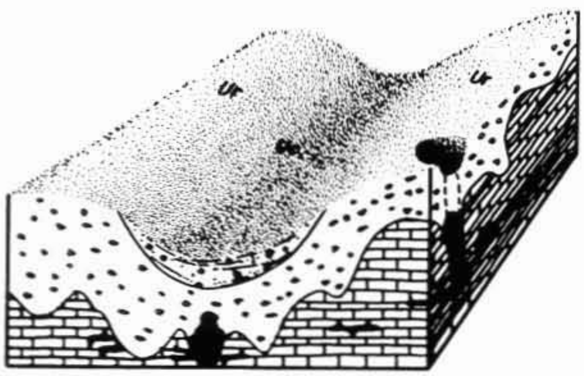

Figure 28
Unit Uc, upland valleys with colluvial soil over residual soil.

ENGINEERING GEOLOGY: The colluvial soil (Unit Uc) in the upland valleys has a moderate to low permeability and is suitable for small ponds or lagoons.

Small catastropic collapses can occur though because some voids or caves may be present in the red residual soils (Unit Ur) that underlie the colluvial soil of Unit Uc. Voids are more inclined to occur on the sides of basins or valleys, but may be infrequently encountered beneath the floors. They are not as likely to form beneath valley floors because erosion and soil deposits fill or destroy the voids.

LAKES: Small lakes or ponds can be constructed in Unit Uc but there is a risk that catastropic collapse may occur beneath the lakes or ponds.

There is no easy way to tell if voids are present in the soil and, many times, voids are only uncovered when colluvial soil (Unit Uc) is stripped from the lake basins for use as borrow material. Collapse may also occur when soil roofs over voids are weakened by water saturation. Water from a pond or lake may soak into the underlying soil and, if voids are present beneath the water, the soil roofs--weakened by water sat-

uration--will collapse, and allow the water to drain out.

If lakes or ponds are to be built, then the colluvial soil (Unit Uc) on the surfaces of the valley slopes and floors should not be disturbed. Soil for constructing the dams should come from the hilltops or from parts of the valleys above the water line.

If economically possible, the soil in the lake or pond basins should be disked and then recompacted to decrease soil permeability. An added, although dubious benefit, is that vibrations caused by heavy machinery during disking and compacting of the soil will encourage collapse of voids, thus forewarning of additional voids.

Small ponds may dry up in the summer because there is insufficient inflow of water to balance water losses into the permeable soil and losses due to evaporation.

LAGOONS: Unit Uc is generally suitable for lagoons, but excavations should be kept to a minimum so that the underlying red soil or weathered bedrock is not exposed. The colluvial soil of Unit Uc should be disked and then compacted to decrease permeability. Gravel zones exposed inside the lagoons should be over-excavated 24 inches and brought back to grade with compacted clay. If at all possible, lagoons should be constructed on the surfaces of valley floors with little or no excavation.

Deep excavations for lagoons may encounter voids and weathered bedrock. Costly remedial treatment can range from plastic liners to chemically treated soil pads.

Lagoons situated in sinkholes are hampered because effluent cannot drain out. When effluent seeps into sinks, groundwater pollution is intensified.

LANDFILLS: This is not a favorable unit for landfills because trench-type landfill operations would penetrate Unit Uc and bottom in stoney red soil or weathered bedrock. Voids, which may be present in the subsoil beneath the landfills, may collapse, allowing leachates to escape directly into openings in the soil and bedrock.

RECEIVING STREAMS: Streams in this unit are dry most of the year and though brief flows occur after rains there are no sustained flows.

Valley floors are almost flat with very little gradient. Creek channels are poorly defined to non-existent and many creeks are losing. Water in the stream channels will not stay on the surface but enters permeable soil in the valley floors and openings in the underlying bedrock. Once the water enters these openings, it can travel long distances through cave-like passages. The flow may reappear on the surface as a spring further down the valley or sometimes in an entirely different valley.

UNIT Va

Valleys with alluvial and colluvial deposits of gravel, sand, silt, and clay over bedrock. Bedrock outcrops are not unusual (fig. 29).

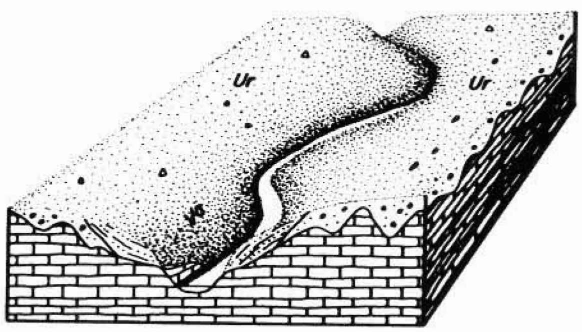

Figure 29
Unit Va, valleys with alluvial and colluvial deposits of gravel, sand, silt and clay over bedrock.

TOPOGRAPHIC SETTING: This unit is situated in second order alluvial valleys that are tributaries of the major creeks and river valleys in the Springfield area. Streams in this unit contain both gaining and losing reaches. Stream flow measurements made by the U.S. Geological Survey indicate there are stretches of water loss in Terrell Creek (Republic Quadrangle), Pearson Creek (Galloway Quadrangle), and South Dry Lac (Ebenezer and Bassville Quadrangles).

Streams in this unit generally have surface flow during the winter and spring. During the summer or dry period streams may dry up completely with the exception of their lower reaches which have surface flow most of the time.

Losing segments of streams occur where stream water enters the gravel or permeable bedrock under the stream channel. Flow measurements indicate resurgences of stream water downstream from losing segments. This may indicate that water lost in the losing segments of a stream stays in the valley and reappears further downstream in the gaining portions of the stream.

Stream channels are well defined. Sycamore trees are common along stream channels.

UNIT THICKNESS: 0-10 feet in valley floors
0-10 feet in valley slopes

SOIL: Valley floors are covered by alluvial deposits of gravel, sand, silt, and clay, from 0 to 10 feet thick. In many places, bedrock crops out in stream channel floors. The valley slopes contain colluvial deposits of silt, gravel, and clay. In the lower portions of the watershed, these slopes may be steep and rugged with extensive bedrock outcrops and little soil cover.

Soil in the valley floors show signs of sorting and transportation. This is evident in gravel lesnes exposed in the banks of creek channels.

BEDROCK: Several types of bedrock occur in this unit. Cherty limestones usually are present in the upper part of the watershed. At lower elevations in the central and lower parts of the valley, shale or dolomite may be encountered.

ENGINEERING GEOLOGY: Construction on the valley floors should be planned with consideration of the possibility of flooding. Some of the valleys have large watersheds and flash flooding is possible during times of heavy rainfall.

LAKES: Construction of small lakes or ponds in this unit will be restricted by the widths of the valleys, soil types, and condition of bedrock. Constructing a dam across the principal valleys to form a lake will be an expensive undertaking. Bedrock on the sides and floors of the valleys may be weathered and permeable. Rock should be excavated to seat the trench in tight bedrock. Test borings should be made to determine rock conditions at the proposed dam sites. Losing reaches of streams indicate that there are permeable soil or bedrock conditions and these potential lake sites should be approached with considerable suspicion or avoided.

Small lakes could be constructed across the mouths of the smaller valleys that drain into the larger principal valley of this unit. Ponds or small lakes can be located at the toes of gentle slopes where colluvial clays have accumulated.

LAGOONS: Most of Unit Va is suitable for lagoons. Lagoons discharging into losing segments or located directly upstream from losing segments would have to upgrade effluent quality and receive approval from the Division of Envirnomental Quality.

Soils on the valley floors may be gravelly, requiring over-excavation and padding with compacted clay to prevent leakage from the lagoon.

Lagoons excavated more than 3 feet deep may encounter ground water and bedrock. Such sites may require an intercepter trench around the outside of the lagoon at an elevation lower than the lagoon floor, to intercept shallow ground water flowing through the alluvial soils in the valley bottoms.

LANDFILLS: This unit is not suitable for landfills due to inadequate soil thicknesses, variable soil compositions, and shallow ground water.

RECEIVING STREAMS: The lower reaches of streams in this unit flow most of the year but those in the upper half of the watershed may be dry part of the year. Streams in Unit Va receive their water supplies from perched water tables or local springs, most of which are in the watersheds where the valleys are situated.

UNIT Vb

Valleys with alluvial and colluvial deposits of poorly sorted gravel, sand, and silt. Bedrock sometimes crops in the creek channels (fig. 30).

TOPOGRAPHIC SETTING: This unit is situated in second order valleys that are tributaries to major creeks and river valleys (Unit Vc) in the mapped area.

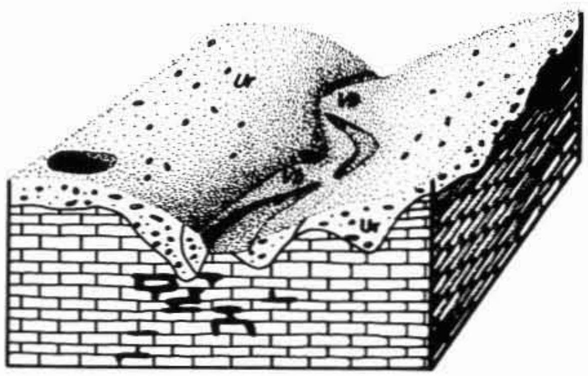

Figure 30
Unit Vb, valleys with alluvial and colluvial deposits of poorly sorted gravel, sand and silt.

Streams in this unit are dry most of the year. Water entering the streams seeps into permeable soil or bedrock under the valleys.

The stream channels in this unit change in physical appearance several times along the stream courses. For short distances, some streams will have distinct channels with steep banks several feet high. A stream channel may be entrenched in the valley floor with easily recognizable boundaries. Its appearance may aburptly change as the channel becomes weed choked and obscured by piles of leaves or tree limbs carried in by runoff from the last rainfall. The stream gradient may flatten and the channel floor may be covered by chert cobbles and boulders. In some valleys, the stream channels may be less than a foot wide even though the watershed draining into the valley may be over 100 acres.

KARST AREAS: Sinkholes may be in or along the borders of this unit.

UNIT THICKNESS: 0-10 feet in the valleys.

SOIL: Valley floors are covered with poorly sorted boulders and gravel. Occasional deposits of gravelly clay and silty clay may be found in the floodplain of the larger valleys.

BEDROCK: Bedrock consists of weathered limestone and contains numerous joints and fractures which have been enlarged by solution weathering.

ENGINEERING GEOLOGY: This unit is poor for any type of water-holding structure or landfill. Where the bedrock surface is very uneven due to weathering, foundation excavations are difficult and expensive. Drilling of piers and piling is also hampered by the weathered bedrock's uneven surface.

LAKES: This unit is poor for lakes due to permeable soil and bedrock conditions. Lakes should only be considered in this unit after drilling and pressure testing programs indicate that geologic conditions are suitable.

LAGOONS: If lagoons are to be located in this unit, synthetic liners or thick clay pads will be necessary to prevent leakage. Construction costs will be above average because of adverse geologic conditions.

LANDFILLS: This unit is a poor location for landfills due to the permeable soils and bedrock. Leachates entering openings in the bedrock may contaminate water supplies.

RECEIVING STREAMS: Most of the receiving streams in this unit are considered losing. Sewage effluent entering the receiving streams stays on the ground for short distances only before entering permeable soil. Effluent may move through permeable soil or bedrock and reappear in springs farther down the valley. In some cases, effluent may move long distances beneath the surface through passages in the bedrock and contaminate springs in other valleys.

UNIT Vc

Broad valleys with alluvial deposits of gravel, sand, silt, and clay over bedrock (fig. 31).

TOPOGRAPHIC SETTING: This unit is situated in first order valleys containing large rivers or creeks such as Wilson Creek, Finley Creek, James River, and Pomme de Terre River. In some locations, the valleys are more than a half mile wide.

UNIT THICKNESS: 5-30 feet.

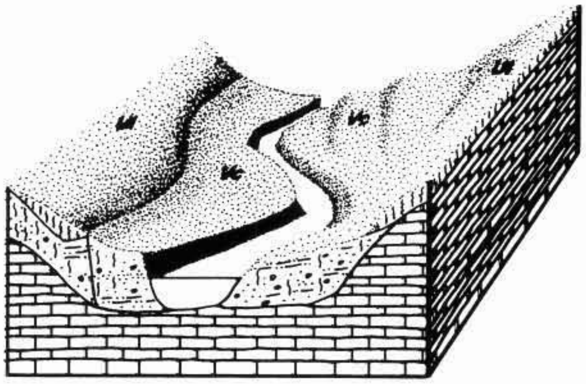

Figure 31
Unit Vc, broad valleys with alluvial deposits of gravel, sand, soil and clay over bedrock.

SOIL: Soils in this unit are alluvial in origin with the exception of colluvial soils at the foot of valley slopes. Discontinuous lenses of gravel, silt, and sand are present. Thick sequences of silty and sandy clay occur in the alluvial flood plains and terraces.

BEDROCK: Bedrock under this unit is limestone, shale, and dolomite. Carbonate bedrock is severely weathered on the valley slopes. Bedrock bluffs that overlook the valleys contain caves, solution-enlarged joints, and bedding planes. Generally, the bedrock under the valley floors is not as weathered as that on the slopes.

ENGINEERING GEOLOGY: Generally this unit is suitable for small lakes and lagoons and for limited landfill uses. Thick sequences of clay interfingered with gravel zones are present in the broad alluvial flood plains that border the rivers.

LAKES: Small lakes can be located in the floodplain, but the best sites are generally along the bases of hillsides where the floodplain and valley slopes meet.

Soils at the bases of slopes are usually clayey because erosion processes have washed clay down from the adjoining uplands. Further out on the floodplain, excavations for water holding basins may encounter permeable gravel layers or ground water. Because of the floodplain's flat surface, the amount of water draining from the watershed into the basin is usually limited to the circumference of the basin.

Other possible lake locations are in the small tributary valleys that enter the larger valleys of Unit Vc. Bedrock and soil conditions in these valleys vary, so some type of foundation investigations should generally be made.

The extent of foundation investigations needed in these smaller valleys depends on the size of the proposed lakes. Larger sites need a combination of drill borings and backhoe pits to properly identify geologic conditions, while backhoe pits alone may be sufficient to answer questions about soils and bedrock at smaller sites.

Large lakes, such as would be formed by constructing a dam across the James River or Finley Creek, would require extensive drilling programs to determine bedrock qualities. The weathered condition of bedrock may call for extensive rock excavation and grouting to construct a stable dam and to prevent

lake water from leaking through the abutments. Dewatering may be needed for excavation of cutoff trenches.

LAGOONS: Generally this unit is suitable for lagoons. However, if plans require a deep excavation for the lagoon, ground water or permeable gravel layers may be encountered. Terraces containing clay-rich soil make excellent lagoon sites. Planning and design of lagoons should consider the lagoon's location on the floodplain and the maximum height that floodwaters reached in the past. The lagoon should be situated where it will not restrict or impede the movement of floodwater across the floodplain and cause water to back up behind the lagoon.

LANDFILLS: Landfills may be located in this unit, but preliminary investigations should be made to determine the types of soil, depths to bedrock, and the elevation of the water table. The best locations for landfills are at the feet of slopes or on terraces where soils are usually more clayey.

Landfills should be situated at elevations where they will not be affected by floodwaters.

UNIT Sr

Hillslopes with residual soil over weathered shale (fig. 32).

TOPOGRAPHIC SETTING: This unit is situated in northeastern Greene County on hillslopes which are a part of the Eureka Springs Escarpment. The unit trends northwest to southeast across northeastern Greene County. The hillslopes on which Unit Sr is located, are steep to gentle and range from 50 to 100 feet in height.

UNIT THICKNESS: 3-8 feet.

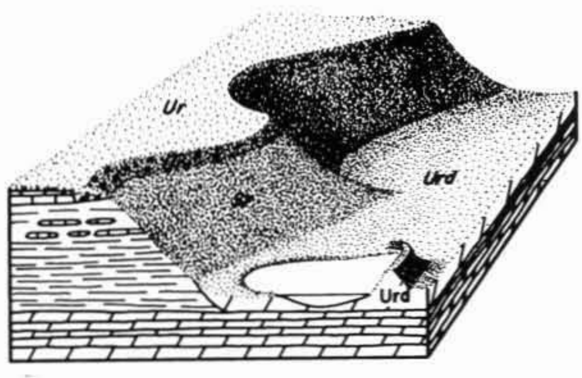

Figure 32
Unit Sr, hillslopes with residual soil over weathered shale.

SOIL: Unit Sr is silty clay formed from weathering of the underlying Northview Shale and siltstone. It has a low permeability and loses much of its strength when wet.

Soil of this unit is sometimes mixed with cherty red clay that has been washed down from Units Ur or Ul. These upland units are above Unit Sr and form a colluvial mixture of chert gravel, siltstone boulders, and silty clay on the hillslopes.

In some locations, the surface of this unit contains large rectangular siltstone boulders that may be from 1 to 2 feet thick. These may be troublesome when excavating.

BEDROCK: Bedrock is primarily shale from the Northview Formation with layers of siltstone in the upper portion of the formation. The Northview ranges from 5 to 80 feet thick. It reaches its maximum thickness near Northview, Mo. and Fairgrove, Mo. and then thins rapidly to less than 5 feet to the south near Rogersville.

ENGINEERING GEOLOGY: This unit is primarily on hillslopes. Slides may occur when Unit Sr is placed on some steep slopes as fill. Failure occurs when this fill exceeds its moisture and slope limitations.

The siltstone portion of the Northview is hard and may require drilling and blasting to remove the thicker ledges. The shale can be excavated by bulldozer or backhoe.

Many of the springs in this region are found at the top of the Northview Formation.

LAKES: This unit is excellent for water impoundment structures if suitable topography can be found. The steep slopes limit the sizes of lakes. The best sites are at the bottoms of slopes where colluvial clay occurs.

LAGOONS: This unit is excellent for lagoons with preferred locations being at the bases of slopes.

LANDFILLS: This unit is suitable for landfills in northeastern Greene County. The best locations are where the unit is underlain by a thick impermeable shale layer that will impede the downward percolation of leachates.

RECEIVING STREAMS: Usually wet weather streams. Most streams have steep gradients which result in rapid runoff of surface water.

UNIT Urs

Uplands with soil formed from weathering of sandstone (fig. 33).

TOPOGRAPHIC SETTING: This unit, an association of sandy soil and sand-

stone, occurs as a widespread layer on hilltops or as isolated patches on uplands. It is found extensively on the hilltops of northwestern Greene County between Walnut Grove and Willard, Mo. Deposits occur locally in the northeastern corner of Greene County where sandstone crops out on hilltops.

UNIT THICKNESS: 1-5 feet.

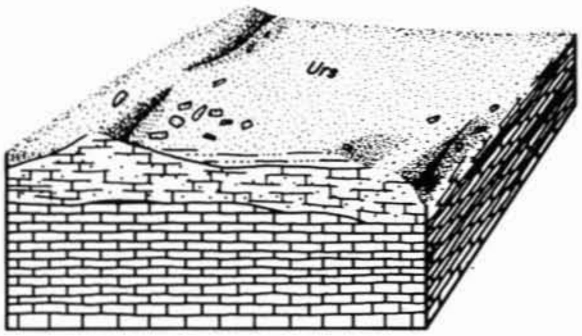

Figure 33
Unit Urs, uplands with soil formed from weathering of sandstone.

SOIL: The soil, a mixture of clayey sand and sandy clay containing scattered sandstone fragments, is formed from weathering of the underlying sandstone. The sandstone is thick to thin bedded and ranges in hardness from very hard to soft and friable.

In many places there is no soil on top of the sandstone bedrock. Large masses of sandstone boulders may be found on hillsides within this unit.

ENGINEERING GEOLOGY: This unit may have poor water holding capabilities due to its very sandy soils. Before lakes or lagoons are constructed, tests should be made to determine the soil's permeability. A simple test would be to dig a pit 5 or 6 feet deep and fill it with water. The rate at which the water level declines would indicate the soil permeability.

This material usually has good bearing capacity and should be well suited for light loads. Foundations for heavy loads should be placed on the underlying bedrock.

Uneven bedrock surfaces may be encountered when excavating basements or utility trenches.

LAKES: Soils in this unit may be very permeable due to the sand content, so permeability tests should be made before lakes or ponds are constructed. To keep water impoundments from leaking, some type of sealant such as bentonite or a clay blanket should be spread over the interiors of the lakes or ponds.

Erosion of Urs soils may cause siltation in lakes and ponds if grass or some sort of cover is not maintained around the shores.

LAGOONS: Lagoons in this unit require remedial treatment such as bentonite, a well compacted clay pad, or a plastic liner to prevent leakage. Deep excavations for lagoons may encounter bedrock. A backhoe pit or auger boring

should be completed before lagoons are constructed to find depths to bedrock.

LANDFILLS: Unit Urs is not favorable for landfills due to insufficient soil cover and to permeable soil. The permeability of the underlying bedrock also detracts from landfill suitability.

RECEIVING STREAMS: Most of the streams located in this unit are in the upper part of the watershed and will generally be dry during most of the year. Little dilution can be anticipated in these streams.

UNIT Urd

Uplands with thin soil cover over weathered dolomite (fig. 34).

TOPOGRAPHIC SETTING: This unit is on flat to rolling terrain in northeastern Greene County. Sandstone crops out on many of the hilltops above 1,300 feet in elevation.

UNIT THICKNESS: 1-10 feet.

SOIL: This soil, developed from weathering of the underlying dolomite, consists of a silty clay containing scattered chert gravel, cobbles, and boulders. Where sandstone occurs, the soil is sandy and may contain chert gravel and thin, flat sandstone boulders.

Weathering of the underlying dolomite produces a light-colored plastic clay. At the base of hills on which Unit Sr occurs, soils from Unit Urd mix with the colluvial soils of Unit Sr and form an excellent soil for impoundments.

BEDROCK: Bedrock beneath this unit is primarily thick- to thin-bedded silty dolomite. Various sized layers of sandstone occur at different elevations in the dolomite, some of which are less than an inch thick while others are over 5 feet thick. The more massive sandstone crops out on hills above 1,300 feet in elevation. Large desk- to piano-

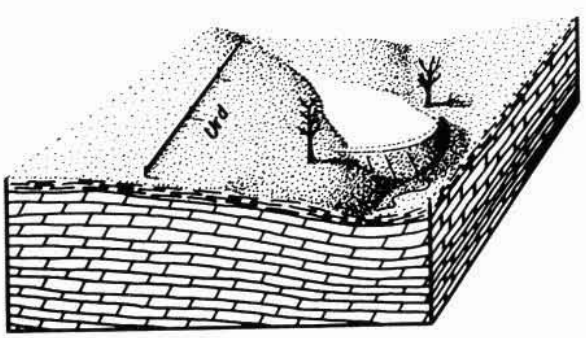

Figure 34
Unit Urd, uplands with thin soil cover over weathered dolomite.

sized boulders of chert on some hillslopes (NE, SW, Sec. 8, T. 30 N., R. 19 W.) may be remnants from a formation that has been destroyed by weathering.

ENGINEERING GEOLOGY: Generally this unit is well suited for water impoundments but landfill sites are limited because of the thin soil cover.

Bedrock beneath this unit is not as severely weathered as the limestone beneath Units Ur, Ul, and Vb; solution openings are not as numerous in the dolomite as in the limestone. Karst areas are non-existent. The silty dolomite weathers into a plastic clay that has low permeability when compacted.

Excavations for utility trenches, foundations, and basements will probably encounter bedrock. The bedrock is hard and drilling and blast excavations may be necessary.

Springs sometime occur in this unit where sandstone crops out on slopes of deep valleys.

LAKES: This unit is well suited for water impoundments. The soil may be gravelly but it usually has enough clay so that it can be used for dam construction.

Cut-off trenches should be excavated beneath dams to prevent lake water from leaking around the ends or beneath the bottoms of the dams. These cut-off trenches should be excavated into tight bedrock and then filled with compacted clay. Dams are then constructed on top of the trenches. By placing the trenches in tight bedrock, cracks or openings in the bedrock are sealed so lake water cannot leak out.

LAGOONS: This unit is suitable for lagoons. No unusual problems are anticipated although soil cover may be thin in some places. If a deep lagoon must be constructed to provide gravity flow of effluent, then bedrock excavation may be necessary. Bedrock should not be exposed inside a lagoon because of the possibility of lagoon fluid leaking into bedrock fractures. Levees should be constructed in front of rock cuts to prevent leakage.

It may also be necessary to place interceptor trenches around the outsides of lagoons to intercept shallow ground water.

LANDFILLS: Good landfill sites are difficult to find here because of the thin soil cover. Exploratory pits should be dug to determine soil thickness at sites of proposed landfill construction. Where the soil is thick enough, generally 15 feet or more, this unit is excellent for landfills. Some minor seepage from perched water tables may be encountered in the trench landfills and soils may be gravelly in some places, but these are items that can usually be solved by engineering studies and techniques.

RECEIVING STREAMS: Most of the streams in this unit are gaining. Those with small watersheds may dry up during dry periods. There may be instances where creek water does enter

fractures in the bedrock, but these fractures are not widespread or extensive. Water may enter the fractures, flow a short distance underground, and then reappear on the surface. Any water loss is usually local.

UNIT Sa

Slopes with thin soil cover over bedrock (fig. 35).

TOPOGRAPHIC SETTING: Situated on moderate to steep slopes with 0 to 5 feet of soil cover. Bedrock is exposed on most of the steep slopes. This unit can merge with the residual soil of Unit Uc on gentle to moderate slopes.

UNIT THICKNESS: 0-5 feet.

SOIL: Soil on the slopes can vary from clayey silt to silty gravel with small amounts of clay. Occasionally small layers or pockets of clay can be found on the rocky slopes. Many of the moderate slopes bordering the large river valleys contain layers of gravelly clay that have washed down from upper hillslopes. These layers can be over 5 feet thick.

BEDROCK: The bedrock under this unit is deeply weathered limestone and dolomite and, where exposed on the slopes, may contain open joints, caves, or fractures.

ENGINEERING GEOLOGY: The steep slopes, thin soil cover, and deeply weathered bedrock make this a poor unit for lakes, lagoons, and landfills. The steep topography hampers construction projects, and excavations for basements or utility trenches usually encounter bedrock.

Remedial engineering procedures are more involved and costly because of the adverse geological conditions.

LAKES: Construction of lakes in this unit should proceed with caution. All lake sites should have a geological examination or a foundation investigation. The bedrock is usually extensively weathered and may contain a network of underground openings. Trying to seal the bedrock openings after a lake has been constructed is generally costly, frustrating, and futile.

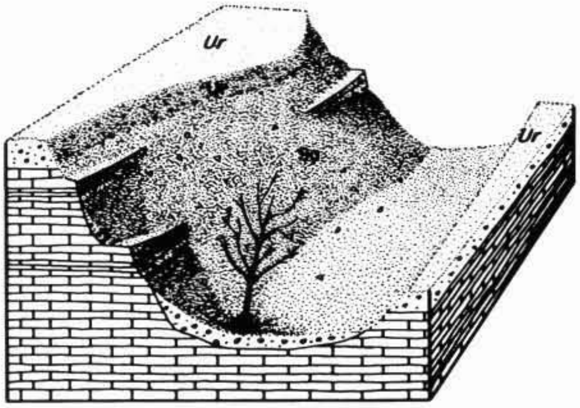

Figure 35
Unit Sa, slopes with thin soil cover over bedrock.

Water impoundments should have cut-off trenches beneath the dams. Cut-off trenches should be excavated into tight bedrock and then back filled with clay. Cut-off trenches help prevent lake water from leaking around the ends and beneath the dams. Excavation of cut-off trenches may require expensive rock excavations in order to seat trenches in tight bedrock.

LAGOONS: This unit is generally not favorable for construction of lagoons because of the steep slopes and the thin soil cover. Bedrock is extensively and highly permeable. If lagoons must be located in this unit, higher construction costs should be anticipated. The interiors of lagoons will need clay or artificial liners to prevent leakage.

LANDFILLS: This unit is not recommended for landfills due to thin soil covers, weathered bedrock, and steep slopes.

RECEIVING STREAMS: Streams in this unit are usually dry due to small watersheds. Also, the hillslopes cause speedy runoff of surface water and there is little storage to replenish flow. Due to the weathered bedrock, many of the streams that cross this unit are losing so the water generally does not stay on the surface, enters openings in the bedrock and travels beneath the surface.

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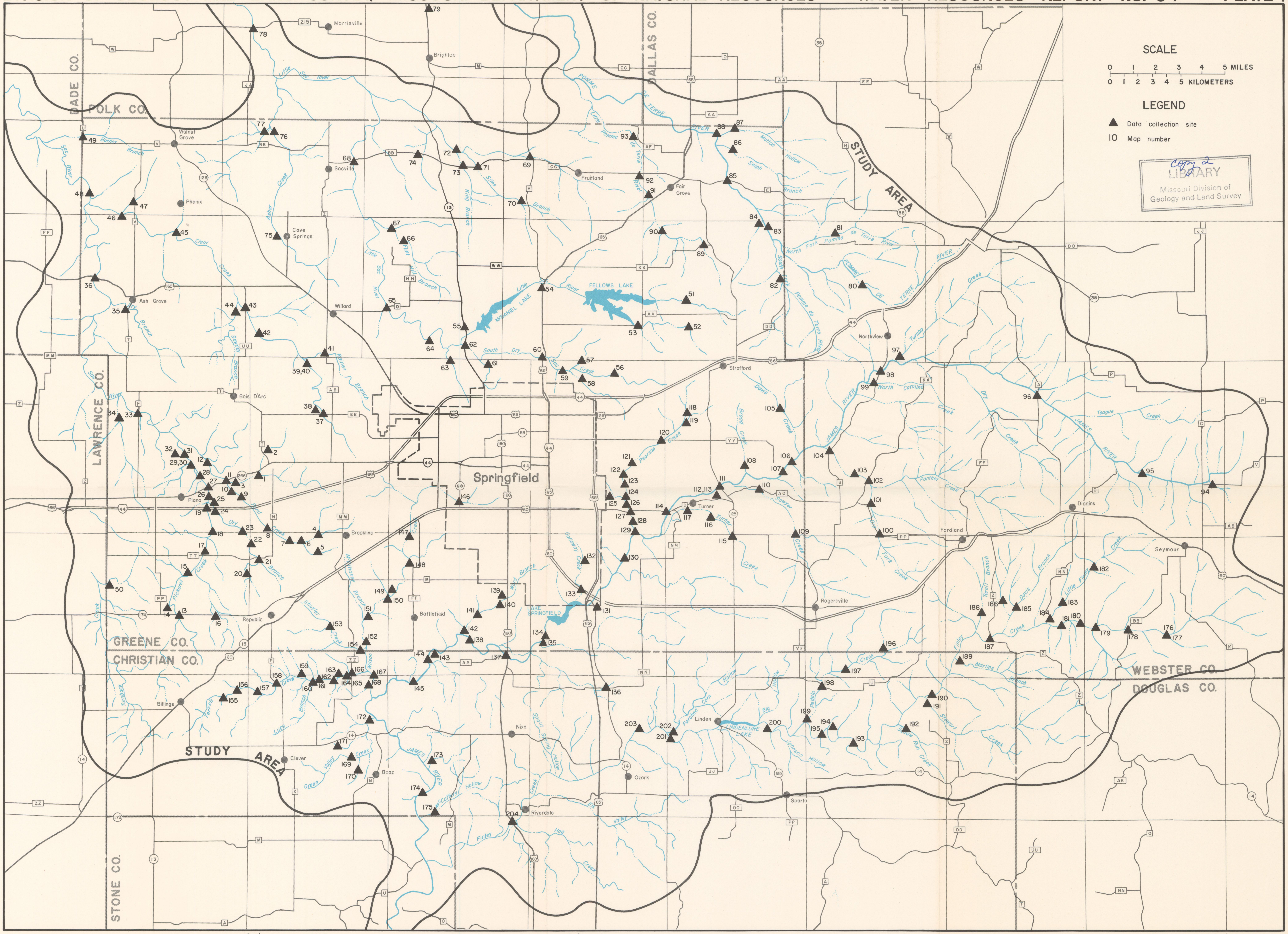

BASE FROM MISSOURI HIGHWAY DEPARTMENT
COUNTY HIGHWAY MAPS 1:125,000

STREAMFLOW DATA-COLLECTION SITES IN THE SPRINGFIELD AREA, MISSOURI

1977

BY JOHN SKELTON

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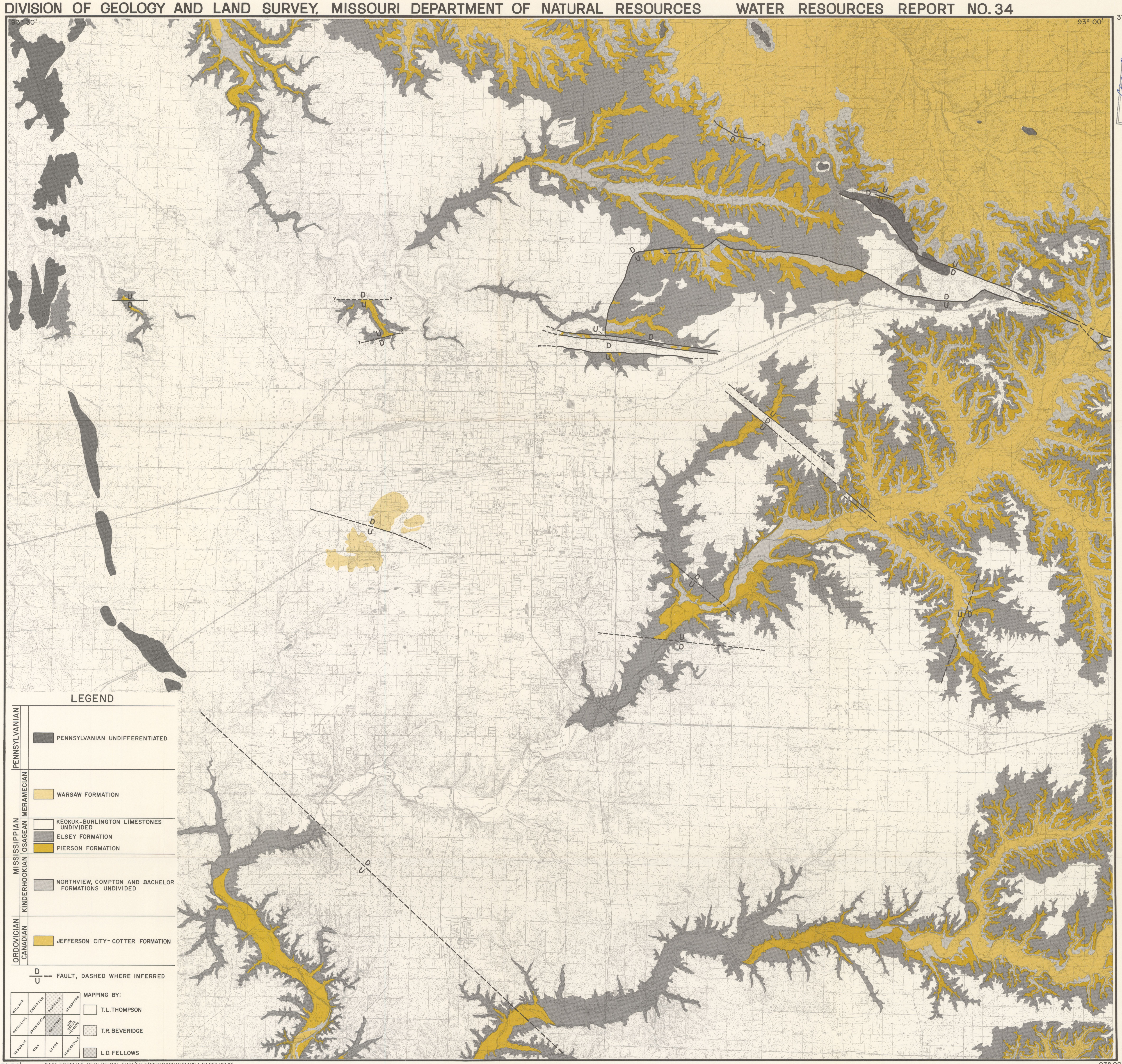


BASE FROM U.S. GEOLOGICAL SURVEY TOPOGRAPHIC MAPS 1:24,000 (1970). BASSVILLE, BROOKLINE, EBENEZER, GALLOWAY, NIXA, OAK GROVE HEIGHTS, OZARK, REPUBLIC, ROGERSVILLE, SPRINGFIELD, STRAFFORD, WILLARD. CONTOUR INTERVAL 20 FEET IN SOUTHEAST PART OF MAP AND 10 FEET ELSEWHERE.

GEOLOGY OF THE SPRINGFIELD AREA, MISSOURI

SCALE

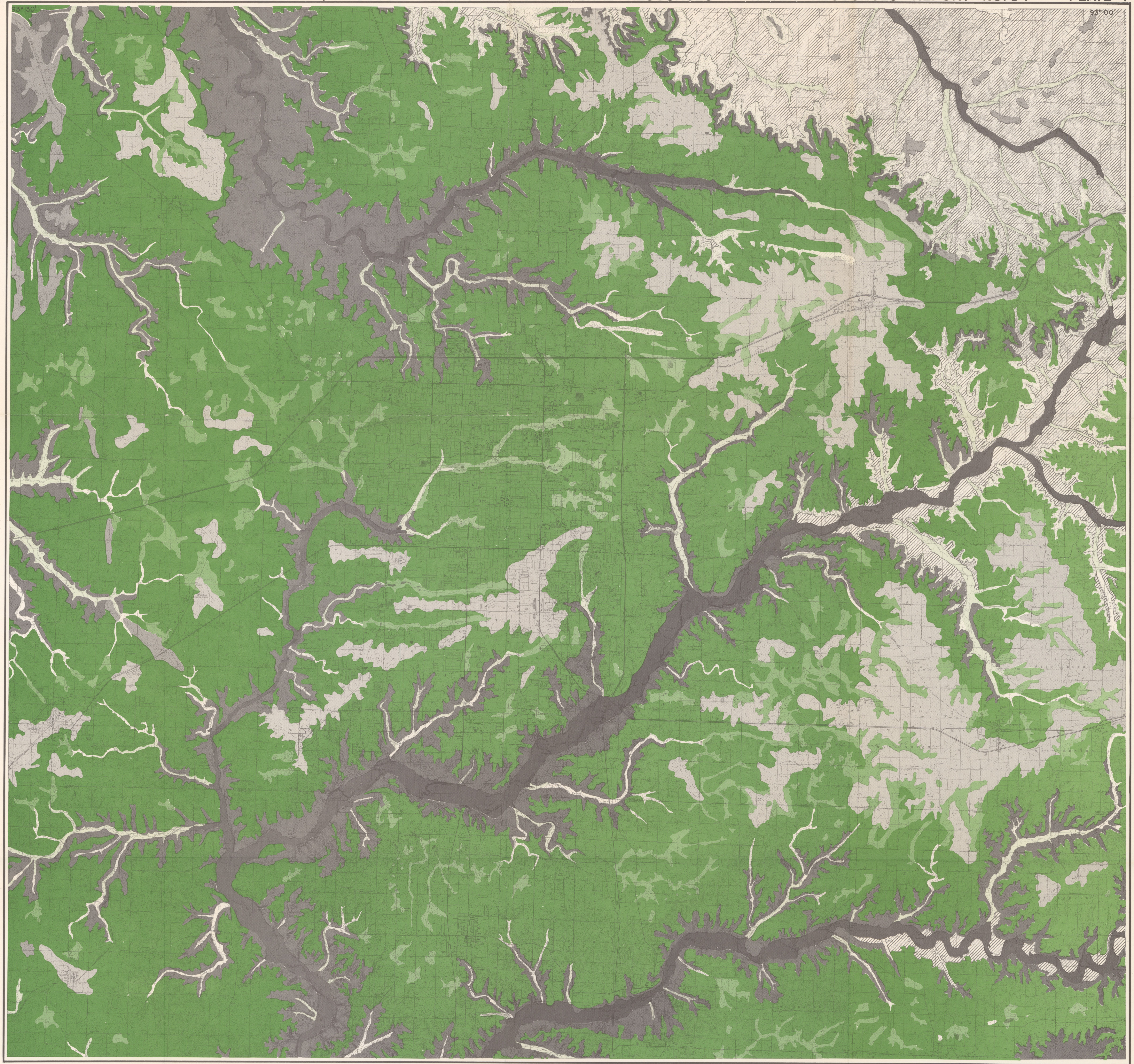
0 1 2 MILES

0 1 2 KILOMETERS

POTENTIOMETRIC MAP OF THE DEEP AQUIFER IN THE SPRINGFIELD AREA, MISSOURI

AS OF JUNE 1974

BY LEO F. EMMETT, JOHN SKELTON, R. R. LUCKEY AND DON E. MILLER



ENGINEERING GEOLOGY OF THE SPRINGFIELD AREA, MISSOURI

1977

BY JOHN W. WHITFIELD

SCALE
0 1 2 MILES
0 1 2 KILOMETERS

LEGEND

Symbol	Description
Ul	UPLAND, LOESS CAP OVER RESIDUAL SOIL; BEDROCK IS WEATHERED LIMESTONE.
Ur	UPLAND, RED CHERTY CLAY RESIDUAL SOIL OVER WEATHERED LIMESTONE.
Uc	UPLAND VALLEYS AND LARGE SINKS, COLLUVIAL SOIL OVER RESIDUAL SOIL; BEDROCK IS WEATHERED LIMESTONE.
Urs	UPLAND, SANDY SOIL FORMED BY WEATHERING OF SANDSTONE.
Urd	UPLAND, GENERALLY CLAYEY SOIL FORMED BY WEATHERING OF DOLOMITE.
Va	VALLEY, ALLUVIAL AND COLLUVIAL DEPOSITS OVER BEDROCK; STREAMS USUALLY GAINING BUT MAY HAVE LOSING SEGMENTS.
Vb	VALLEY, ALLUVIAL AND COLLUVIAL DEPOSITS OVER BEDROCK; NUMEROUS LOSING STREAMS.
Vc	LARGE VALLEYS, ALLUVIAL DEPOSITS OF GRAVEL, SAND, SILT, AND CLAY; WIDE FLOODPLAIN.
Sr	SLOPES, CLAYEY RESIDUAL SOIL FORMED FROM UNDERLYING SHALE AND SILTSTONE.
Ss	SLOPES, THIN STONY SOIL COVER OVER WEATHERED LIMESTONE AND DOLOMITE.